Mees, Charles Edward Kenneth
The photography of coloured objects

Negative by André Callier, Ghent, on Wratten Colour-Sensitive Plate

AN ALPINE LANDSCAPE

The PHOTOGRAPHY OF COLOURED OBJECTS

BY
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PREFACE

THIS book represents an attempt to put clearly the theory underlying the photography of coloured objects, and the application of that theory to those branches of practice which are of the most immediate importance.

The need for such a book has been impressed upon me by my daily correspondence, and I have hopes that it may serve as a kind of text-book of the subject for many of my friends.

While not employing purely scientific nomenclature and phraseology, I have made no attempt to be "practical," believing as I do, that the application of an ounce of *accurate* knowledge is worth a ton of *unreasoning* practice. I have also made no pretence as to being unbiassed, I have frankly discussed the products of my own firm, but I hope that the loss of generalisation caused by this procedure will be compensated by the advantage to be gained from definite information.

It would not be possible, for instance, usefully to discuss the distribution of sensitiveness in "red-sensitive plates," whereas it is quite possible to discuss the distribution of sensitiveness in any particular plate. I am also likely to be biassed in argument, but I have not allowed myself to be *consciously* biassed, and have tried to be as fair as possible.

I am very much obliged to many friends for the services chronicled below.

Chapter VI. on "Photography for Reproduction," was written by Mr. A. J. Newton.

Chapter VII. on "Landscape Photography," was largely drafted by M. André Callier.

Chapter V. was criticised by Mr. F. M. Sutcliffe, who made very many suggestions, and also by Mr. H. A. Hutchinson, Mr. Furley Lewis, Mr. E. A. Salt, and Mr. W. H. Smith.

Chapter VII. was criticised by M. André Callier, Mr. J. C. S. Mummery, Mr. W. T. Greatbatch, and Mr. W. R. Bland.

The line illustrations were specially drawn, with the exception of fig. 22, which is taken from A. König's paper on "Sensation Curves" (*Zeitschrift fuer Psychologie*, iv. 241).

For the half-tone illustrations, I am indebted to M. Callier for the frontispiece and the other two mountain views, to Mr. Hutchinson for the landscape, and to Mr. Greatbatch for the meadow view.

The furniture photographs I owe to the kindness of Messrs. Maple, Ltd., and of Mr. Erwood ; the rest, with the exception of the portraits by Mr. Barraud, and the photographs of the *Mauretania*, which I owe to Mr. Edgar Lee, of Messrs. Thompson & Lee, were made in my laboratory.

The cover is from a design by a student of the London County Council School of Photo-Engraving and Lithography.

C. E. KENNETH MEES.

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THE PHOTOGRAPHY OF COLOURED OBJECTS

CHAPTER I

The Nature of Colour

AT the commencement of this book, which is essentially concerned with the analysis and photography of colour, it will be well for us to get a definite idea as to what is meant by "colour," and with what physical phenomena colour is associated.

The nature of colour is involved in the conception we obtain as to the nature of light. The nature of light has long been a source of speculation, and it was generally held that perception of light depended on the reception by the eye of small discrete particles shot off from the source of light; just as at one time it was held that the perception of sound depended upon the impact upon the ear drum of small particles shot off from the sources of the sound. This theory of light has the advantage that it immediately explains reflection; just as an indiarubber ball bounces from a smooth wall, while it will be shot in almost any direction by a heap of stones, so these small particles would rebound from a polished surface, while a rough surface would merely scatter them. This theory of the nature of light appeared adequate until it was found that it was possible, by dividing a beam of light and slightly lengthening the path of one of the halves, and then re-uniting them, to produce periods of darkness similar in nature to the nodes produced in an organ-pipe, where the interference of waves of sound is taking place. It could not be imagined that a reinforcement of

one stream of particles by another stream of particles in the same direction could produce an absence of particles, while the analogy with sound suggested that, just as sound was known to consist of waves in the air, so light also consisted of waves.

Light cannot consist of waves in the air, partly because we know that it travels through interstellar space, where we imagine that there is no air, but also because the velocity of light, nearly 200,000 miles per second, is so great that it is impossible that it could consist of a wave in any material substance with which we are acquainted. It is, however, supposed that there must exist, spread through all space and all matter, a substance which is termed the ether, and that light consists of waves in this ether.

Now, just as in sound we have wave notes of high frequency, that is, with many waves per second falling upon the ear, which form the high-pitched or shrill notes, and also notes of low frequency, where only a few waves per second fall upon the ear, forming the bass notes—so with light we may have different frequencies of vibration, some falling upon the eye at very short intervals, while other waves are of only half or even less frequency.

Since the velocity of light is the same for waves of different frequencies, it is clear that the waves of high frequency will be of shorter wave length than those of low frequency, the length of a light wave being the distance from the crest of one wave to the crest of the next.

The wave length of the light, like the velocity, will vary with the medium in which the light is travelling. For instance, when light is travelling through glass, it will only have about two-thirds of the wave length of the light travelling in the air. But it is convenient to consider simply the wave length of light as the length of the wave in free ether, or for practical purposes, in air. White light consists of vibrations of many degrees of frequency, *i.e.* it consists of waves of various lengths; and a mixture of waves of all lengths in certain proportions, forms what we term white light. If instead of allowing this heterogeneous mixture of waves to fall upon the eye, we

omit waves of some frequencies from those entering the eye, then the brain will receive a sensation of colour. Thus colour is associated with wave length. White light being made up of waves of different lengths may be regarded as being made up of light of various colours, and by different devices may be split up into these colours. When this is done there is obtained what is known as the spectrum.

Fig. 1 shows the average length of wave corresponding to light of various colours, the diagram being drawn to scale. Since different lengths of wave correspond to different colours, the spectrum corresponds to a scale of different length waves. The following diagram gives a simple arrangement of the spectrum, the numbers representing the length of the waves in Ångström Units (A.U.), which are tenmillionths of millimetres, and the colours being placed against them:

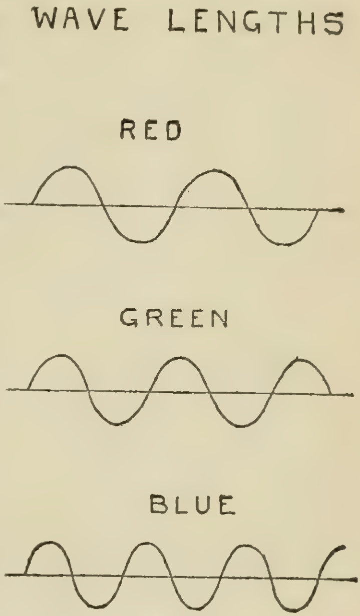

Fig. 1

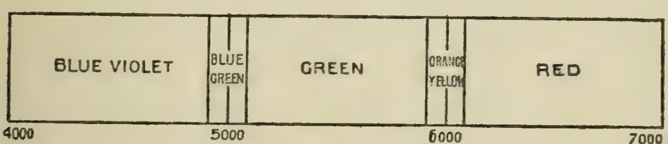

Fig. 2

It will be seen that the visible spectrum extends from 7000 to 4000, and is equally divided into regions which may be broadly termed—

Red	. . . .	7000 to 6000
Green	. . . .	6000 ,, 5000
Blue-violet	. . .	5000 ,, 4000

If we make a filter which only lets through the portion of the spectrum between 6000 and 7000, then we should call that filter a red filter, a filter letting through from 5000 to 6000 would be a green filter, and a filter letting through from 4000 to 5000 would be blue-violet in colour. Thus from the spectrum we already derive the idea that light can be divided into three colours which we may call the primary colours, red, green, and blue-violet.

Remembering this conception of light, let us consider why we term a given filter red. It will appear red because it only lets through red light, but white light consisting of red, green, and blue-violet is falling upon it, so that clearly it is red because it stops or absorbs the green and blue-violet light.

Similarly, a piece of red paper is red because it reflects red light, but it has falling upon it white light consisting of red, green, and blue-violet, so that it must absorb the green and blue-violet light, not reflecting them, and only reflecting the red light. We are therefore justified in saying that anything which absorbs green light and blue-violet light together will be red.

It is this aspect of colour, that objects are coloured because they absorb, which must be clearly and definitely understood if the best results are to be obtained in the photography of coloured objects. Unfortunately, however, the conception of colour as an absorption is not common, though I believe it to be the most useful one, and it will be necessary for me to somewhat elaborate this subject in order to prevent misconceptions arising. It seems to me that we should form the habit of considering a red object, not as one that reflects red, but as one that absorbs green and blue-violet.

The importance of this definition is that it defines "red" without reference to the colour of the incident light. Take a scarlet book and examine it by a light containing no red; such for instance as the mercury vapour lamp, in which red is almost entirely wanting. The book will no longer reflect red light because there is no red light for it to reflect, but it will still absorb the green and blue-violet light of the lamp, looking black; it has not changed its nature, and we should still

be justified in saying that it is red if we define red as we have done above.

In the same way a yellow object is not one which reflects yellow light (there is very little yellow light indeed in the spectrum, and if an object reflected only yellow light it would be so dark as to be almost black), but a yellow colour is due to blue absorption. It reflects the other two components of white light, green and red, so that we should be justified in saying that yellow light consists of green light plus red light, but for our purpose I want to consider yellow simply as a lack of blue; yellow is minus blue,

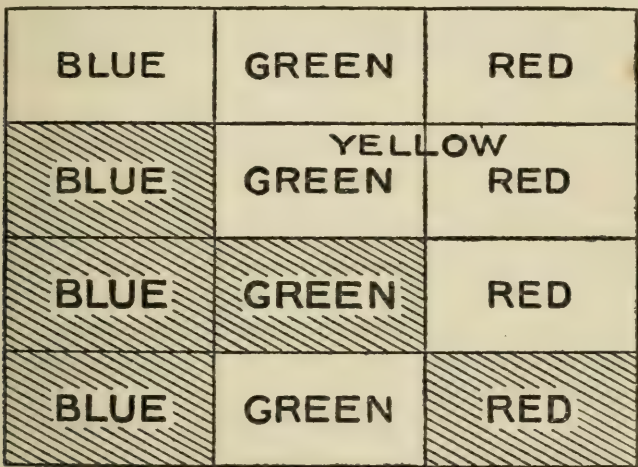

Fig. 3

so that if you have a beam of yellow light and add blue light to it, you will get white light.

Now what is green? Well, since white light consists of red light, green light, and blue light, green is clearly white light minus red and minus blue; and a green body is one which absorbs both red and blue. The difference between a green object and a yellow object being that the yellow object absorbs blue only, whereas the green object absorbs some of the red light which the yellow object reflects.

We can now make clear what is meant by complementary colours. As is shown in the diagram (fig. 3), white light con-

sists of red light, green light, and blue light. The next section under this shows the blue blotted out, leaving the mixture of red and green—that is, yellow. We should say then, that yellow is complementary to the blue-violet. In the same way, in the next diagram all green and blue are blotted out, leaving only red, so that red is complementary to green-blue. In the bottom diagram all red and blue are blotted out, leaving only green; green is complementary to this blue-red mixture, which is usually known as magenta.

In general, then, the light absorbed by an object may be said to be complementary to that reflected by it.

So far we have only considered intense colours. We have imagined that a red object absorbs the whole of the green and the blue-violet light, that is to say that its absorption was complete. But most things have only partial absorption—the absorption is incomplete. Partial absorption can be of two forms: it can be gradual, or it can be sharp; thus, if you take a photograph of a spectrum, and put in front of the spectroscope a solution of erythrosin, then that erythrosin will cut a clean patch of green out of the spectrum between 4800 and 5500, as is shown in the photograph (fig. 4). But if you put in front of the spectrum a cell containing gentian violet you will get a very gradual diminution of intensity between about 4700 and 6200, with the least light transmitted about 5800 (fig. 5). Thus different dyes and different substances give different classes of absorption, the two kinds being roughly subdivided into (1) sharp absorptions, and (2) gradual absorptions.

Let us examine the effect of a single sharp absorption band in different parts of the spectrum. First, consider a sharp absorption band situated in the red about 6500 and producing a total absence of red in this part. The remaining colour consists of all the blue-violet and all the green, with some of the red. The actual visual effect of the mixed colour is what one might term a "sky-blue." Imagine this band to shift so as to absorb the orange; absorbing between 5800 and 6200, the colour will be a light violet-blue, because there is a great deal of red being transmitted and less green. If the band shifts into the yellowish green from 5600 and 6000 it will absorb a great deal of the green and none of the red, and the colour will become bluish purple; as it

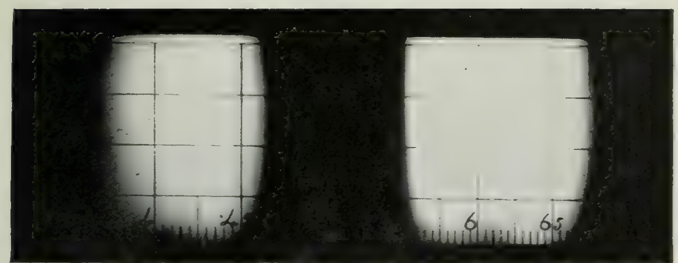

Fig. 4

Erythrosin Absorption Spectrum

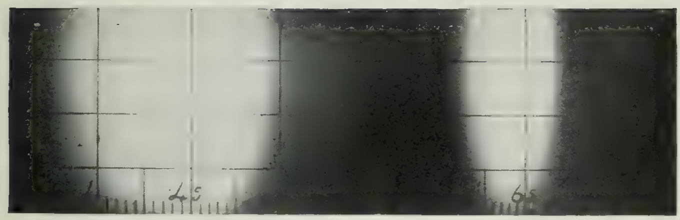

Fig. 5

Gentian Violet Absorption Spectrum

shifts lower in the green towards the blue this purple becomes a reddish purple, so that when the band is situated at from 5600 to 5200 we have what is generally known as magenta in colour. As the band shifts towards the blue, the blue fades out of the magenta, green taking its place. When the band is from 4700 to 5200 the colour is a sort of orange, and as the band moves into the blue-violet the orange becomes a yellow, and finally a lemon-yellow. So

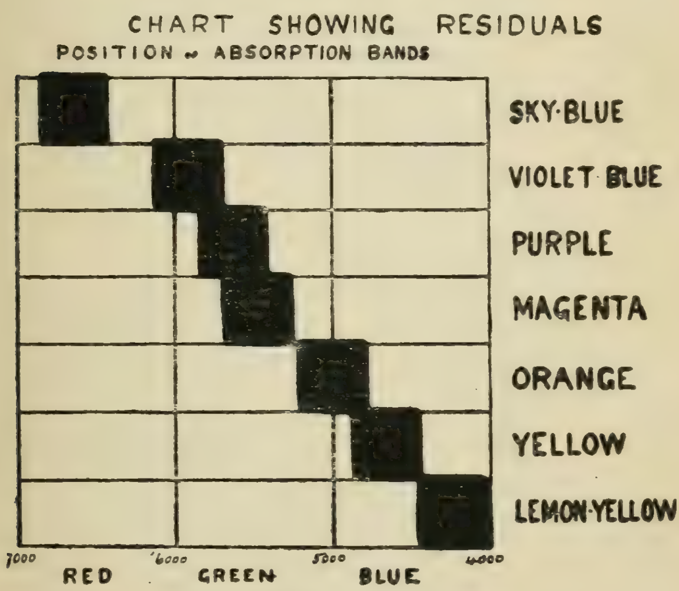

Fig. 6

that if we imagine a single band to pass down the spectrum, we get a change from light sky-blue through purple, magenta, orange, and yellow, to lemon-yellow (fig. 6).

Now it will be seen that there is one class of colour which does not enter at all into this series, namely, the greens. There is really no visual suggestion of green in any colour formed by using a daylight spectrum and absorbing one narrow band only. In order to get a green we must have an absorption both in the red and in the blue. If

we absorb the extreme red and also the extreme blue, we shall at once get a green, and as these two bands vary with regard to each other, we shall obtain various shades of greens. Thus, if the red absorption band is very strong and the blue absorption band is weak, we get blue-greens ; if the red absorption weak, and the blue strong, yellow-greens.

Green is almost the only common colour due to two absorption bands, and other colours which on analysis prove to have two absorption bands generally tend to be mere variants in hue of some colours which we have already discussed under the heading of single absorption bands. A brown colour is fairly common, and the bands of a brown are of a gradual absorption type generally extending through the blue-green with a transmission band in the violet—that is to say, a brown is really a degraded orange, and is a variant on the colour described as orange, resulting from a single absorption band in the blue-green.

Natural colours, however, do not present these sharp absorption bands, the absorptions being always more or less gradual. Thus, in fig. 7, we see a sharp absorption band depicted, which would give rise to a violet-blue colour. An actual violet-blue, however, will have an absorption band of the type shown by the shading in the opposite direction on the diagram. Similarly, fig. 8 shows an ideal green, having sharp red and violet absorption and an actual green with its gradual ending and absorption of the green itself.

The sharpness of absorption bands is of great importance in respect of the luminosity of the colours produced by them. The side of an absorption band, which is toward the red end of the spectrum, generally has a sharp edge, as shown in fig. 7, while that which is toward the blue end has a gradual edge, a considerable amount of absorption remaining even in the transmitted portions of the spectrum. As a result, colours which are bounded by the sharp edges—that is, reds, oranges, and yellows, are bright colours, while colours which are bounded by the gradual edges—blue-greens, blues, and violets, are dark colours. A green will, as a general rule, have a sharp edge at its blue limit and a

gradual edge at its red limit, and will consequently be of intermediate brightness.

If we divide the spectrum at 5000 and at 6000 so that we get three portions, 4000 to 5000 which we may term blue-violet, 5000 to 6000 which we may term green, and 6000 to 7000 which we may term red, then examination of the luminosity curve, given in Chapter II., fig. 9 will show that about $\frac{2}{3}$ of the whole light should be "green," about $\frac{9}{30}$ should be "red," and about $\frac{1}{30}$ should be "blue." But inasmuch as a bright red object will reflect nearly all the incident

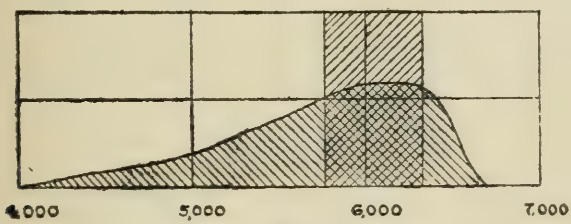

Fig. 7

Theoretical and Actual Violet

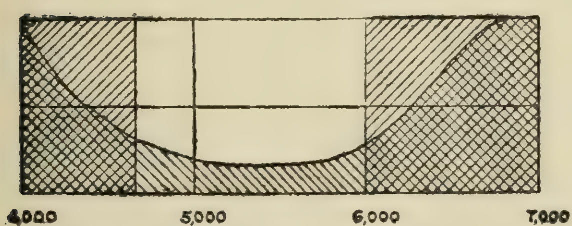

Fig. 8

Theoretical and Actual Green

"red" light, while a bright green object will only reflect about $\frac{1}{3}$ of the "green" light, and a bright blue object $\frac{1}{4}$ of the "blue" light; a red object will be the brightest, a green object less bright, and a blue object very dark indeed.

A yellow, having only a single sharp absorption edge, is very bright. A yellow object usually reflects even more red light than a red object, and much more green light than a green object.

I have made a number of measurements of the absorption by various filters and colours, of the light

which they are supposed to transmit or reflect, with the following results :

PURE DYE FILTERS

Transmitting.	Region for which Transparency was measured.	Trans-parency, per cent.
5900 to red end (tricolour red).	Same filter	75
5900 ,, ,, .	6100 to red end	78
6000 to 4800 (tricolour green) .	Same filter	32
6000 to 4800 ,, .	5800 to 4900	35·5
5100 to 4000 (tricolour blue) .	Same filter	11·5
5100 to 4000 ,, .	4800 to 4000	16·5
4700 to 4000 (D. methyl violet)	4600 to 4000	15
5600 to red end (E) . .	Same filter	69
5600 ,, . .	5900 to red end	85
5100 to red end (G) . .	Same filter	79
5100 ,, . .	5600 to red end	89
5400 to 4000 (H) . . .	Same filter	14
5400 to 4000 ,, . . .	5100 to 4600	16
4600 to red end (K2) . .	Same filter	72·5
4600 ,, . .	K3	85
K3	K3	81
K3	5100 to red end	86
Light naphthol green (about 6500 to 4500) . . .	5700 to 4900	40
Dark naphthol green . .	5700 to 4900	14·5
Xylen red (5100 to 4000), purest blue obtainable . . .	4700 to 4000	41

The chief points of interest are the luminosity of the yellows (K2, K3, G); orange (E); and red (A); the darkening in the greens, and even more in the blues and violets.

PRINTING INKS

Bright scarlet . . .	5900 to red end	83·5
,, ,, . . .	6100 ,,	88
Bright light blue . . .	5100 to 4000	42

DYED WOOLS

These were given me by Dr. E. König, of Höchst a/M, and he stated that he considered them to be very good pure colours.

Colour.	Region of Measurement.	Percentage Reflected.
Dark purple	4800–4000	9·5
Bright ,,	4800–4000	22
,, ,,	6500–red end	42
Dark blue	4700–4000	19
Light ,,	5100–4000	18
Dark blue-green	5000–5800	11
Light ,,	4900–5400	25
Dark yellow-green	5000–5800	17·5
Bright ,,	6100–4800	26·5
,, ,,	5000–5800	39
Yellow	5100–red end	67
Orange	5600 ,,	57·5
,,	5900 ,,	70
Scarlet	5900 ,,	61
,,	6100 ,,	68
Bright scarlet	6100 ,,	71
Deep red	6100 ,,	49
,,	6500 ,,	77

CHAPTER II

The Sensitiveness to Coloured Light of the Eye and of Photographic Plates

We have seen that the eye distinguishes light of different wave lengths by the production of an appearance of colour, *i.e.* a ray of light containing waves of a length of 4600 of our units would be called violet, and would be said to be of a violet colour, while if the waves were of the length of 6500 they would be said to be deep red in colour. But the sensitiveness of the eye is not the same for waves of different lengths. The eye cannot per-

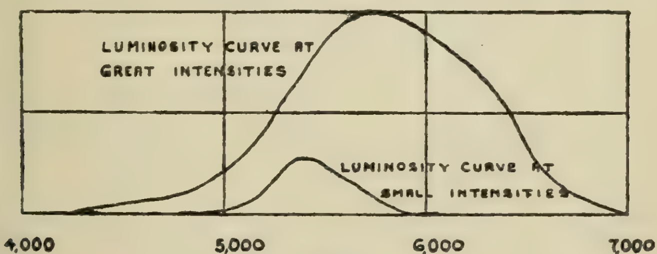

Fig. 9

ceive at all waves below 4000 units, *i.e.* what is known as ultra-violet light; neither can it perceive rays which are above 7000 units, so that to these we must regard the eye as insensitive. The eye is very little sensitive to the extreme violet rays between 4000 and 4500. The blue affects it more and appears, as we say, bright. Between 5000 and 6000 the green appears as the brightest part of the spectrum; above 6000 we have the bright reds, but the intensity rapidly falls off as the waves get longer, until beyond 7000 we see practically nothing. We may then draw a curve

showing the sensitiveness of the eye to the spectrum. It will be noted that this curve has a maximum at about wave length 5900, but this only holds for intense light. As the intensity of the light diminishes, not merely does the eye see less, but the relative sensitiveness of the colours changes somewhat, shifting towards the blue. This is what is known as "Purkinje's Phenomenon." The explanation offered for it by Professor Schaum is sufficiently interesting and little known to be worth repetition. It is known that the retina consists of rods and cones, of which the cones are considered to be colour-sensitive, and the rods colour-blind. In the part of the retina exactly opposite the centre of the pupil there is a small depression which contains no rods, but only cones, and here it is found that the Purkinje phenomenon is non-existent, so that the intensity maximum remains constant. So that we may conclude that the colour-sensitive cones alone display no Purkinje phenomenon, and that the phenomenon is due to the association of these cones with the colour-blind rods. It is found that the sensitiveness curve for this region containing only cones is identical with the curve of sensitiveness for great intensities of light, so that this is the curve of the cones. On the other hand, since the rods are much more sensitive to feeble intensities of light than the cones, as is shown by the fact that the sense of light remains after colour can no longer be distinguished, the sensitiveness curve of the rods will correspond to the curve for minimum intensity; so that for minimum intensity the sensitiveness curve is due to the rods alone, and as the intensity grows the curve is more and more influenced by the cones, until with maximum intensity the curve of sensitiveness is almost entirely determined by the cones.

Just as the eye is unequally sensitive to light of different colours, so a photographic plate is unequally sensitive to light of different colours. But if we take an ordinary photographic plate and measure its sensitiveness, we shall find that it differs very markedly from that of the eye. The eye can see waves of no shorter length than 4000 units; a photographic plate can see very much shorter waves, and can detect light which is quite invisible to the eye, this light being usually called ultra-violet light, because it is beyond the violet. Also

the maximum of sensitiveness of a plate is in the violet, and all the red-orange and nearly all the green light is invisible to it. The eye may be said to perceive objects mainly by the green and orange light which they reflect. The ordinary plate perceives objects by the blue and violet light which

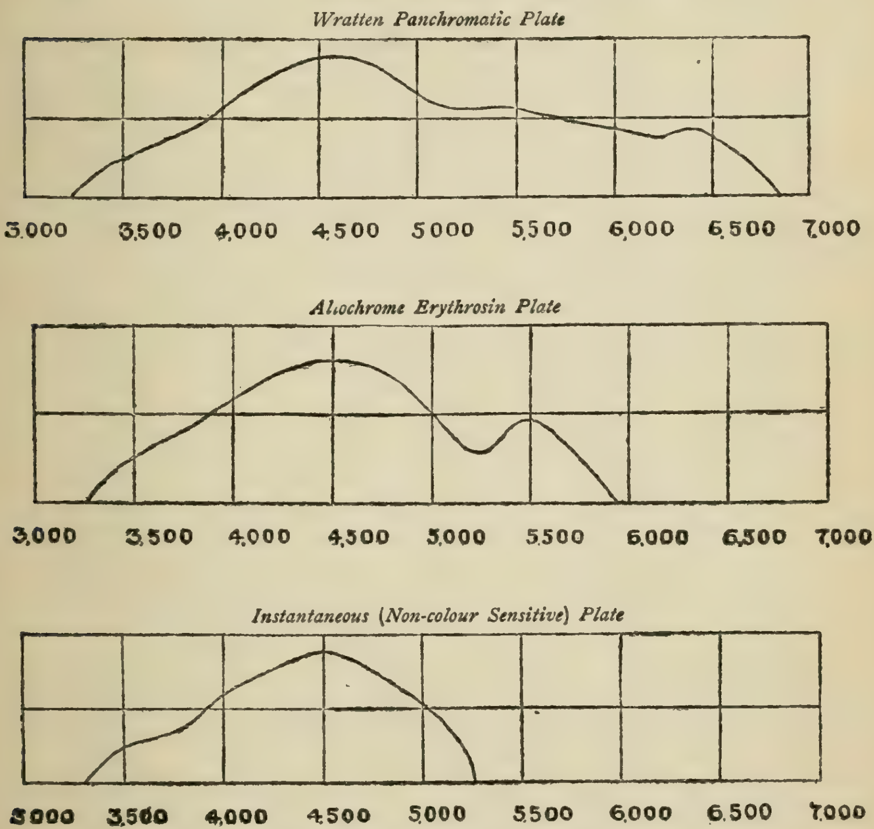

Plate Sensitiveness Curves to Daylight

Fig. 10

they reflect, and this is a great difficulty in the photographic plate when regarded as an instrument for perceiving and recording coloured objects, because the record which a photographic plate makes of coloured objects differs entirely from that which the eye makes.

It was found by Vogel that, by treating plates with dyes,

they could be given, besides their usual sensitiveness, a secondary sensitiveness in approximately the region of the spectrum which those dyes absorb. Thus if a plate is soaked in a solution of Erythrosin, which absorbs the yellowish green, it will be sensitive to the yellow-green, besides being sensitive to the blue and violet. Plates which have been treated in this way are those which are known as "orthochromatic," the word implying that they can render objects in their true colour values. The ordinary commercial orthochromatic plate, which is made by putting some Eosin or Erythrosin into the emulsion, has a sensitiveness curve of the type shown in fig. 10, and it will be seen at once, on comparing this with the sensitiveness curve of the eye, that, although the plate is certainly better in consequence of this treatment with Erythrosin, it cannot be described as at all comparable in sensitiveness with the eye. It has an enormous excess of sensitiveness in the blue and violet, it has the sensitiveness to the ultra-violet which the eye has not at all, it then has very little sensitiveness indeed to the blue-green, a small maximum of sensitiveness in the yellow-green, and an absence of sensitiveness to the red. It may be assumed that if we take the blue to include the whole spectrum up to 5000, the green to be the spectrum from 5000 to 6000, and the red from 6000 upwards, that the sensitiveness of the ordinary orthochromatic plate is distributed in the ratio of 40 parts in the blue, one part in the green, and none in the red. If we consider that the eye sees the three parts of the spectrum as of equal intensity, then the orthochromatic plate besides the fact that it is not sensitive to the red, has only $\frac{1}{40}$ of the sensitiveness in the green that it would require to be equal in sensitiveness to the eye.

If, however, instead of sensitising a plate in the way we have described, we bathe the finished plate in a solution of certain of the new dyes called Isocyanines, we can prepare a plate which is very much more sensitive both to the red and to the green. Two years ago Messrs. Wratten and Wainwright, Ltd., succeeded in preparing a plate in this manner, the plate being sensitive to both red and green, and this plate they called the "Wratten Panchromatic Plate." The plate is sensitive to the whole visible spectrum; although it has a considerable excess of sensitiveness in the blue, this

excess is very much less than in the case of the ordinary orthochromatic plates, and there are no absences of sensitiveness throughout the whole spectrum. The distribution of sensitiveness in this plate is also shown in fig. 10, and it may be said that $\frac{7}{8}$ of its sensitiveness is in the blue, $\frac{1}{16}$ in the green, and $\frac{1}{16}$ in the red; so that the sensitiveness to blue is seven times too great compared with the rest of the spectrum, while the sensitiveness to green and red together is $\frac{1}{8}$ of that required to have the same sensitiveness as the eye.

In order to attain the same relative sensitiveness as the eye, it is necessary with an ordinary orthochromatic plate or with the panchromatic plate, to use absorbing colour filters which shall diminish the excess of blue light, and it is the consideration of these colour filters and of the effect which they will have on the total sensitiveness of the plate, that is, on the exposure required, which must occupy our next chapter.

CHAPTER III

SECTION I.—THE MULTIPLYING FACTOR OF ANY SHARP-CUT FILTER

SUPPOSE that we have a filter which has a perfectly sharp absorption—that is to say, which cuts a clean section out of the spectrum, passing only light between two definite wave lengths, and without any absorption of that light—then, if we wish to find the multiplying factor of this filter, we must consider it in relation to the sensitiveness curve of the plate.

It will be convenient first to consider a filter which does not transmit light below 5000 A.U., *i.e.* which absorbs the

Sharp-cut Filter on Erythrosin and Panchromatic Plates

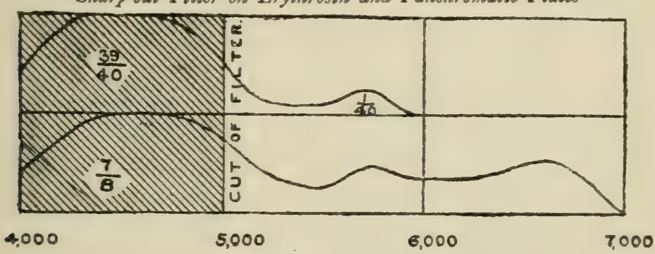

Fig. 11

whole of the blue-violet and ultra-violet, but does not absorb any green or any red. This filter will be a bright yellow in colour, yellow being, as we have seen, made up of green light and red light—that is to say, yellow being simply an absorption of blue. Consider the effect of this on an orthochromatic plate which has $\frac{39}{40}$ of its sensitiveness in the blue and $\frac{1}{40}$ in the green. The yellow screen will remove all the blue light, *i.e.* $\frac{39}{40}$ of the active light, and it will increase

the required exposure 40 times, so that it is what we term a 40 times screen.

Now consider the same screen to be used with the Wratten Panchromatic plate. With this plate $\frac{7}{8}$ of the whole sensitiveness is in the blue, $\frac{1}{8}$ in the red and green. The screen will then remove $\frac{7}{8}$ of the active light, leaving only $\frac{1}{8}$ to act; it will increase the exposure 8 times. This example shows at once the intimate relation between the plate and the multiplying factor of a screen.

Take now a screen cutting the spectrum sharply at 5500. This screen will be bright orange in colour. It transmits all the red, orange, and yellow-green light. It absorbs the blue-violet and blue-green light, *i.e.* adopting our convention as to the division of the spectrum—it transmits the red and half the green, and absorbs the blue and half the green.

Sharp-cut Orange Filter on Erythrosin and Panchromatic Plates

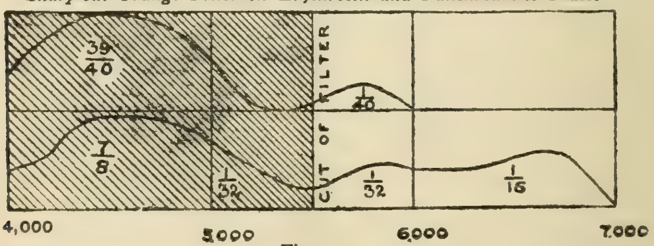

Fig. 12

The effect of this on the ordinary orthochromatic plate is to remove the blue sensitiveness, $\frac{39}{40}$ of the whole sensitiveness of the plate; but inasmuch as this plate is not sensitive to the blue-green, and the yellow-green region of sensitiveness which represents the other $\frac{1}{40}$ of the sensitiveness of the plate is transmitted by the screen undiminished, the screen will only increase the exposure 40 times, being the same increase as is shown by the former screen.

On the panchromatic plate, however, the matter is different, $\frac{7}{8}$ of the sensitiveness of the plate is in the blue, and is removed by the screen, $\frac{1}{16}$ is in the green, and half of this is removed by the screen; so that the sensitiveness left is $\frac{1}{16}$, due to the undiminished red-sensitiveness, and $\frac{1}{32}$, being half of the green sensitiveness—the total residual sensitiveness, therefore, being $\frac{3}{32}$ of the original sensitive-

ness, and this screen will, on the Wratten Panchromatic plate, increase the necessary exposure $10\frac{2}{3}$ times.

Again, consider a screen cutting the spectrum at 6000—that is, transmitting all the red, but absorbing all the blue and all the green. The ordinary orthochromatic plate has no appreciable sensitiveness in the red, and therefore could not be used in practice with such a screen. The Wratten Panchromatic has $\frac{1}{16}$ of its total sensitiveness in the red, and consequently this red screen will, on that plate, be a 16 times screen.

Let us now examine into the multiplying factor of the screen which will give correct reproduction of red, green, and blue, as seen by the eye. We have assumed in all these figures that, in order to get correct reproduction, the sensitiveness for red, green, and blue should be equal; that is,

Orthochromatic Filter on Erythrosin and Panchromatic Plates

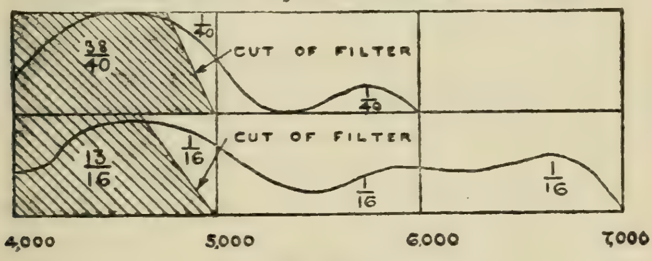

Fig. 13

we have chosen our units with that condition in mind. On the orthochromatic plate we have no red sensitiveness, but the nearest approximation to correct rendering that we are able to obtain will be given if the green and blue are of equal intensities, *i.e.* we require a sensitiveness in the blue equal to the sensitiveness in the green. The sensitiveness of this plate in the green is $\frac{1}{40}$ of its total sensitiveness, so that we must use a screen which will give us $\frac{1}{20}$ of its total sensitiveness, $\frac{1}{40}$ being in the green, and $\frac{1}{40}$ in the blue. That is, it must cut off 38 of the 39 parts of blue sensitiveness which the plate has, and the screen will increase the exposure 20 times.

With the Wratten Panchromatic plate we have $\frac{1}{16}$ of the sensitiveness in the red, and $\frac{1}{16}$ in the green, consequently we must have $\frac{1}{16}$ in the blue · that is, the total sensitiveness

will be $\frac{3}{16}$, and the increase of exposure required by the screen will be $5\frac{1}{3}$ times. This screen will reduce the $\frac{7}{8}$ sensitiveness of the blue to $\frac{1}{16}$, *i.e.* it will remove $\frac{13}{16}$ of the blue sensitiveness. Two points must be noted here:

First that the panchromatic plate will require very much less exposure to fully correct it than will the orthochromatic plate, and secondly that, not only is less exposure required, but that a lighter screen is required; that is to say, in the one case we had to remove all but $\frac{1}{39}$ of the blue, but in the other $\frac{1}{16}$ of the blue was left, and consequently a screen which would give correct reproduction on an ordinary orthochromatic plate will *over-correct* the panchromatic plate.

Section II.—On Orthochromatic Screens

The facts which we have considered will point to some of the conditions which an orthochromatic screen, *i.e.* one which is to produce a greater approximation to the distribution of sensitiveness of the eye than is possessed by the plate, must fulfil. In the first place, the function of an orthochromatic screen is to absorb the blue, and it must not absorb the green, or, if panchromatic plates are used, the red. This disposes at once of two types of screens which are still to some extent in use.

The Brownish Glass Screen.—This screen absorbs some of the blue, but it also absorbs a great deal of the necessary green and even some of the red; so that it is of small practical use, and requires quite unnecessary increases of exposure.

The Green Screen.—This screen has been recommended on the ground that practical trial proved it to give exceedingly good rendering. The actual fact is that a green differs from the yellow in the absorption of the red, consequently if it is used with a plate which is not sensitive to red, the effect of a green screen is identical with the effect of a yellow screen, while if it is used with a plate that is sensitive to red, the green screen destroys to some extent the advantage obtained by using a red sensitive plate. Since also these green screens usually have a considerable absorption in the green itself, they increase exposure to an unnecessary extent, and are therefore inadvisable.

Our screen, then, must be yellow, but it is possible for a screen to be yellow without having the correct absorption. Any screen which absorbs the violet light will be yellow, but it may transmit the ultra violet, and in this way a screen of apparently great depth may be less satisfactory

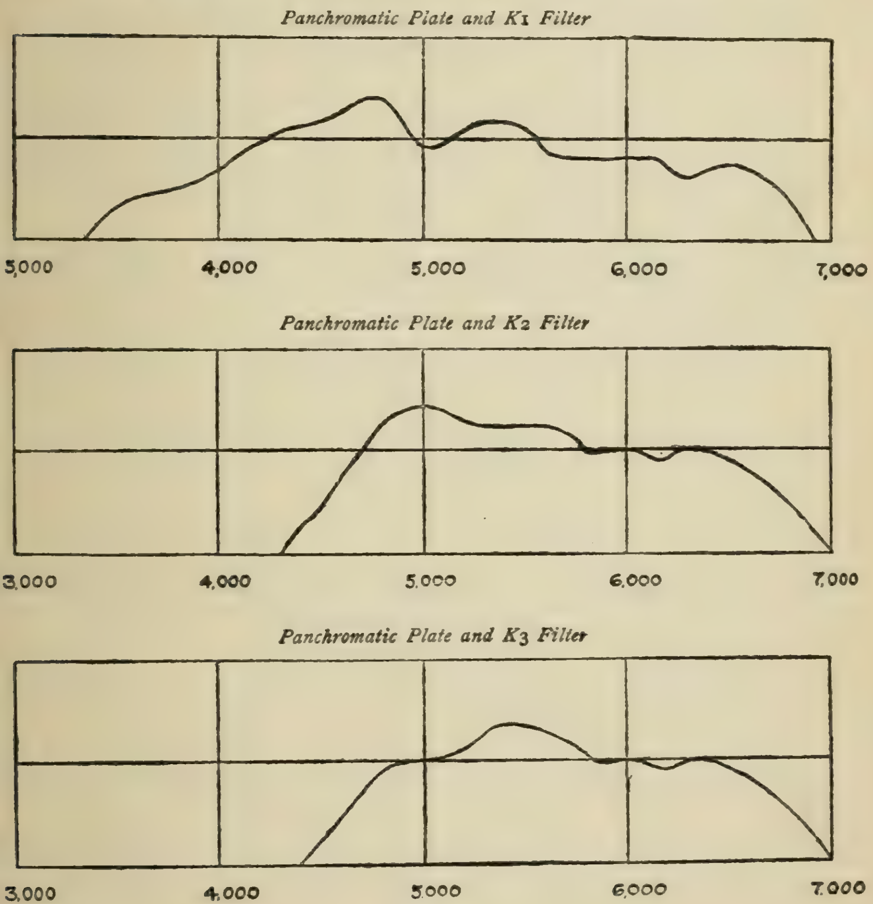

Fig. 14

than a lighter screen having a more complete absorption of the ultra violet.

An orthochromatic screen should, as far as possible, completely absorb the ultra violet, but it should not *completely* absorb any of the visible violet or blue. It must absorb

the visible violet and blue to so great an extent that the photographic effect of the particular plate which is being considered will be equal to the visual effect of these colours. If it absorbs them too completely, a deep violet will appear as black, which clearly is not what is intended, and a screen should therefore not be too sharp-cut in its absorption.

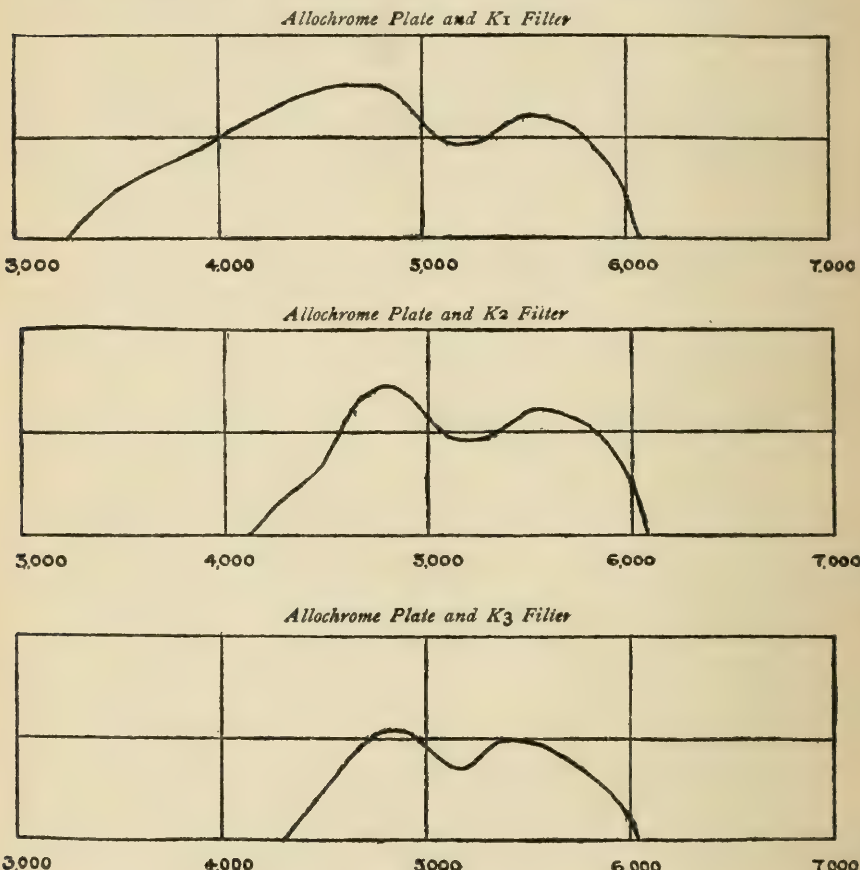

Fig. 15

Now, reflection on the statements of Section I. of this chapter will show that the idea of adjusting a light screen to a particular plate is not really a feasible one at all. It is often stated that particular screens are adjusted to particular plates, but except for the very strong fully correcting screens

which are occasionally used, this is not a fact, and a screen which is satisfactory for one commercial orthochromatic plate will be equally satisfactory for any other, assuming that no attempt is made to *completely* correct either. Since a completely correcting screen for the ordinary orthochromatic plate requires at least twenty times the normal exposure, it is clear that the light screens of commerce cannot be said to be adjusted to the plate in any real sense. The actual curves produced by imposing the Wratten Panchromatic plate behind the three K screens are shown in fig. 14.

It will be seen that with the light K1 screen about half of the whole effect of the plate is in the blue, about $\frac{1}{3}$ being in the green, and $\frac{1}{6}$ in the red. With the K2 screen, the red and green are nearly equally divided, while the blue only has about $\frac{1}{2}$ of the effect of the others. With the K3 the curve approximates to the luminosity curve as seen by the eye. The next illustration shows the effect of these same three screens upon the Allochrome plate (erythrosin). The far less effect of the screens upon this plate than upon the Panchromatic, is worthy of note.

CHAPTER IV

Section I.—The Rendering of Colour Contrasts

By orthochromatic photography, we intend to imply the use of a fully colour-sensitive plate, such as the Wratten Panchromatic, combined with a filter of necessary strength, to give approximately the same tone-rendering as that seen by the eye. It must be remembered in the first place that, to the eye, objects are picked out from their surroundings by contrast, and this contrast may be of two kinds, it may be tone contrast or it may be colour contrast. In the case of tone contrast, if we imagine ourselves to be dealing with a monochromatic scene, any plate will render tone contrast within a considerable range as seen by the eye; but in the case of colour contrast the question will require more careful thought. Suppose that we have two objects, the one superposed upon the other, and separated from each other to the eye purely by their colour contrast; such as a red field containing a patch of green. The contrast between them is marked to the eye, although the tone contrast is very nearly nothing, that is to say, the two are of much the same visual luminosity. If we photograph them upon an ordinary plate both are black to it, and we get our contrast represented by one uniform field of black; the colour contrast has disappeared, and we have a totally unsatisfactory rendering of that which we are photographing. If, however, we photograph them upon a green sensitive plate, then the green will be picked out from the red as brighter, and we shall get a certain degree of contrast of a kind, but if we photograph them upon a panchromatic plate with a K3 screen, so that we get a rendering of both colours in their true luminosity

value to the eye, the contrast disappears, and the colours are represented by a uniform field of grey.

What then must we do to obtain a satisfactory rendering of this colour contrast? Clearly it is not possible to render the colour contrast accurately in monochrome, so long as we retain the rendering of correct luminosity values for our colours, and consequently we must sacrifice the correct rendering of either the red or the green. If we use a lighter filter or a greener filter, the green will appear the brighter and the red the darker; if we use a deep orange filter, the red will be brighter, the green darker; and which we shall do must be governed by circumstances. As a general rule, if we must correct wrongly for the rendering of colour contrast, it is usually better to over-correct towards the red, since red is a strong colour, while green is a weak. For example, in a field of corn of a deep yellow colour, we may have poppies standing out which are nearly as bright as the corn, and it is necessary to decide whether we shall render them as brighter or as darker than the corn. Probably on an actual measurement of luminosities they would be a little darker than the corn, but remembering the way in which the strong red attracts the eye, it would seem that a more faithful rendering would be given by over-correcting and rendering the poppies as brighter than the corn. Again, the top of a yellow haystack against a deep blue sky may give a result with perfect orthochromatism where the haystack is indistinguishable from the background. Here again, I personally should be inclined to over-correct, though the individual worker must decide for himself. A thing to guard against always is the danger of basing one's consideration of monotone rendering upon photographs; few people have been trained in engraving, and photographers are apt to take their conception as to the tone value of bright green grass, for instance, from photographs which invariably show it as dark, if not black. Frequently, in a spring landscape, the hedges and grass are almost the brightest things in the whole landscape, and they should clearly be rendered as light greys; but so uniform is the belief among photographers that grass is black, that a rendering as light grey will almost always provoke the comment that the picture was over-corrected.

Wratten Panchromatic Plate and K3 Filter — *Negative by H. A. Hutchison*

p.

SS. Mauretania

Ordinary Plate — *Edgar S. Lee, Newcastle*

Wratten Panchromatic Plate and K2 Screen — *Edgar S. Lee, Newcastle*

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The most important case of colour contrast occurs in the copying of pictures, and for this purpose I some time ago advised a special method, which it is desirable to explain here.

This method depends upon the use of tricolour filters, the plate being exposed first through one filter and then through another, in order to get the desired colour-rendering. It is first necessary to remove a common misconception, which one frequently finds repeated in text-books and the technical press, namely, that the effect of printing from the three tricolour negatives on one piece of paper would be to give an orthochromatic result. This would give an isochromatic result, that is to say, one in which all colours are rendered of equal strength, independently of their visual brightness; this results in an excess of brightness in the red and blue, especially in the blue, and insufficient brightness in the green, the whole colour-rendering taken this way being wrong. Suppose that we put a set of filters in front of our lens, fitted in a slide-past holder, so that we can expose the plate through the three filters in succession without removing camera or lens. Then we may give an exposure through the three filters, in proportion to their ratio upon that plate. Supposing, for example, that we have a plate and a set of filters, such that the blue requires 6 times the normal exposure, the green requires 12 times the normal exposure, and the red requires 18 times the unscreened exposure, if we give through the blue twice the normal exposure, the plate will be $\frac{1}{3}$ exposed. Now give through the green 4 times the normal exposure—the plate is now $\frac{2}{3}$ exposed—and now superpose on this an exposure through the red screen of 6 times the normal exposure; we have now a negative combining our three colour negatives in one; but it will not be correct rendering at all, it will give all blues much too light, and greens too dark, and the results will be unsatisfactory. With the Wratten filters and plate, owing to the fact that the green transmits a certain amount of blue, correct colour-rendering is obtained by giving $\frac{2}{3}$ of the exposure through the green and $\frac{1}{3}$ through the red. Thus, in the example just given, where the ratio of exposures for the three filters was 6–12–18, the correct rendering would be obtained, together with correct exposure, by giving

about 8 times the normal exposure through the green and 6 times through the red. Since this proportion of the mixed exposures of green and red gives a correct orthochromatic result, we can exaggerate red or green by increasing the exposure of the one filter and diminishing the exposure of the other. For instance, if we give 9 secs. exposure through the red, and 6 secs. through the green, we shall have exaggerated red at the expense of green; on the other hand, if we give 10 secs. through the green and 3 secs. through the red, we shall exaggerate greens at the expense of reds. If we want to diminish greens altogether, and bring up reds and blues, we can use our red filter and blue filter, and so obtain the rendering that we desire by altering the relative exposures through the three tricolour filters.

This method may sound rather far-fetched, but as a matter of fact it has been adopted by some very skilled picture copiers, and in each case where it has been adopted they have, I believe, been perfectly satisfied, and have never gone back to a multitude of yellow screens. A very important point about this method is that all the while one is working one knows how far one is from correct rendering, so that instead of more or less over- or under-correcting by a screen of which the action is somewhat uncertain, one can say quite definitely: "I exaggerated the reds in that reproduction 50 per cent., because it was necessary to pick out the red against the green in the shadows"—a statement which is more scientific and more useful, both to the speaker and hearer, than a statement such as, "I used a rather dark screen for that in order to get over-correction."

A word of warning is necessary here as to the quality of the filters required for this. It will be seen that the three images are literally superposed upon one another, and that the very smallest shift in any one of these images will produce a double image in the result, consequently a much higher grade of filter is required than for ordinary reproduction purposes. It is not sufficient that the images should be of the same size, but they must actually fall on the same place on the focussing glass. This can only be accomplished by the use of filters cemented in optical flats of the very highest quality, or else by the use of gelatine film alone. It will save disappointment if I emphasise the fact that what

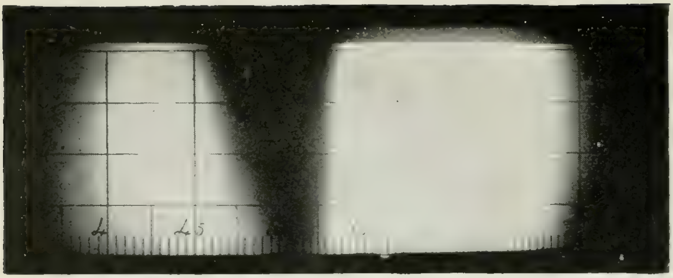
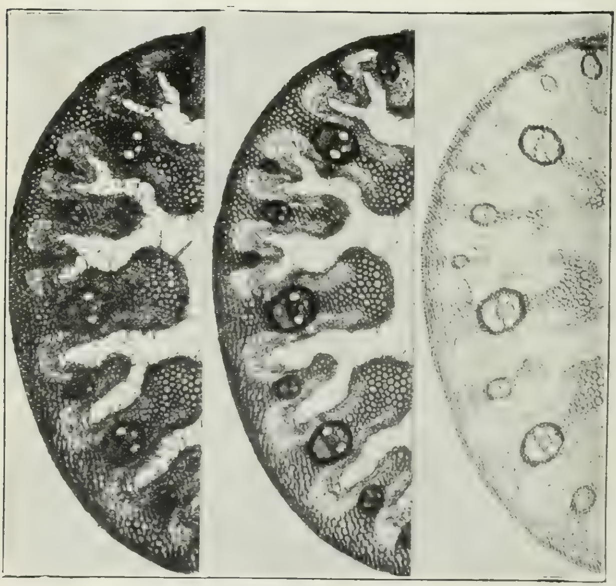


Fig. 16

Absorption of Eosin



W. L. of Light

5000—5400 5700 6400

Fig. 17

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are usually known as "first-class cemented filters" will not do for this.

SECTION II.—COLOUR CONTRAST FOR SPECIAL PURPOSES.

The type of colour contrast which we have been describing is simply a concession from orthochromatism, in order to enable us to some extent to make up for the failure of monotone rendering when it is necessary to render colour. But there is another case of the photography of colour contrast, which is to the technical worker of as great if not greater importance, and that is the photography of coloured objects, *per se*, in order to obtain the best possible results, generally for reproduction purposes.

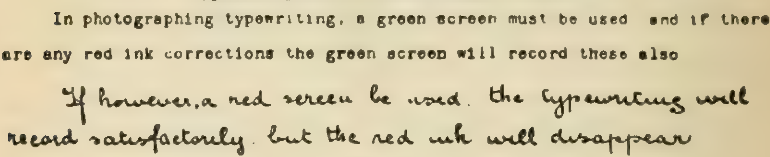
General Principles.—If a colour is to be rendered as black it must be photographed in its absorption band (see Chapter I.) by light which is of such a wave length that it is completely absorbed by the colour. That colour then appears as black as it can be made. A useful example is given by a photo-micrograph of a section stained with eosin: this section is pink; if it is viewed by blue light, owing to the fact that eosin does not absorb blue, it looks comparatively light. By green-blue light of a wave length about 5000 to 5400, which is completely absorbed by eosin (the absorption-spectrum of eosin is shown in fig. 16), the section is entirely black, as is shown by the first block; being blocked up in detail, this gives the maximum degree of contrast (fig. 17). Photographing at 5700, on the border of the absorption band, we get a greatly lessened contrast, which for this particular section will give us the best result. There is plenty of detail in the section, while at the same time the contrast is sufficient for reproduction purposes. Photographing at 6400 in the red, and in the light which is completely transmitted by the section, the section has no contrast, is very flat, and results are useless. So that for the maximum contrast we must photograph in the absorption band. Let us take two practical instances:

Given an engineer's blue print, showing white lettering on a blue ground. We require to reproduce it for a line block. This blue print has a strong absorption in the red. If we photograph it through an A screen, the strong red

screen used for tricolour photography, or better, through the F screen made specially for this work, upon a Process Panchromatic plate, which is quite sensitive to this deep red light, then we shall get the maximum contrast which can be obtained, and, as a matter of fact, the blue will be to all intents and purposes an intense black, so that there is no difficulty whatever in obtaining our negative.

Suppose, to take another example, we have a sheet of typewriting, with corrections in red ink ; the violet type-

Typewriting and Red Ink through B Filter


In photographing typewriting, a green screen must be used and if there are any red ink corrections the green screen will record these also

If however, a red screen be used, the typewriting will record satisfactorily but the red ink will disappear

Fig. 18

writing absorbs the whole of the orange and green, the red ink absorbs only the green. If we photograph through the green filter, B, of the tricolour set, we shall get both the typewriting and the red ink completely black, and therefore the greatest contrast which can be obtained (fig. 18). If, on the other hand, we photograph through the red A filter, the typewriting will appear plainly visible, but the red ink will show so little contrast that it can easily be

Typewriting and Red Ink through A Filter

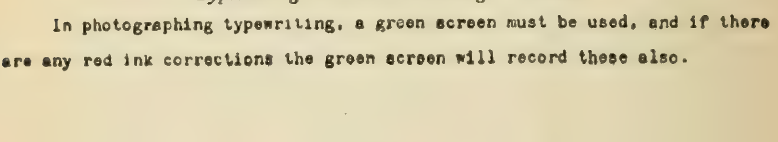

In photographing typewriting, a green screen must be used, and if there are any red ink corrections the green screen will record these also.

Fig. 19

intensified out of existence, and we can make a reproduction of the sheet showing the typewriting only (fig. 19).

By the application of this principle we can pick out, in fact, any colour from a combination of colours, and in two, three, or four printings obtain a facsimile result. For the application of this principle to photomicrography, in which it is of great importance, see a little booklet published by Messrs. Wratten & Wainwright, Ltd., some time ago, entitled "The Selection of Plates and Filters for Photomicrography."

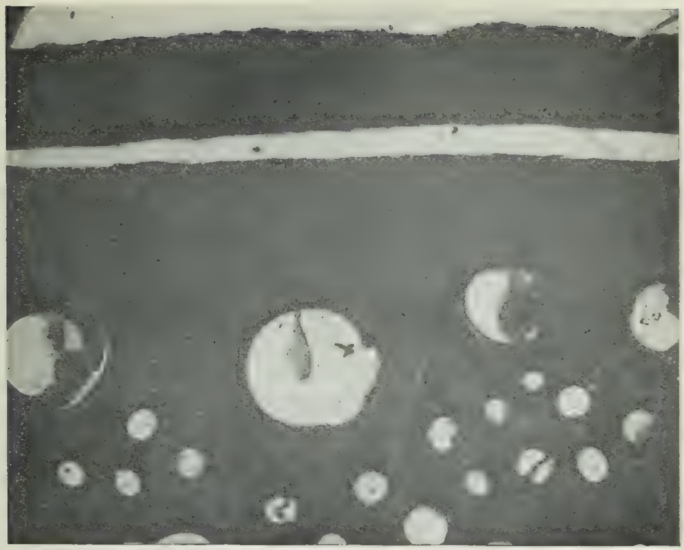


Fig. 20

Whalebone Section Photographed for Contrast

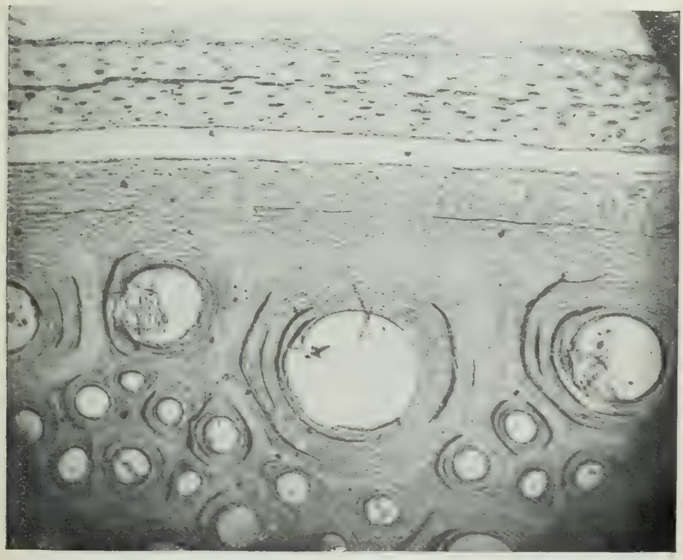


Fig. 21

Whalebone Section Photographed for Detail

On Ordinary Plate

On Wratten Panchromatic Plate through Red Screen

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The second principle of importance is that, where a uniformly coloured thing is to be photographed, and the best rendering is to be obtained, it must be photographed not in its absorption band, but in the transmission or reflection region of the colour. For instance, in photographing the eosin-stained section, we get the greatest contrast by photographing in the absorption region of the stain ; but we obtain that contrast at the expense of the loss of detail in the section, and we get the greatest detail in the photograph where we used the red light. Owing, however, to the fact that we must keep contrast against the *background* in this case, our best final result was a compromise between contrast and detail, obtained by photographing on the border of the absorption band. A very good example, however, of the use of light, such as is transmitted by the stain, is shown by the two photographs of a whalebone section, which are reproduced here from the little book on "Photomicrography." The upper one shows the section photographed for contrast by means of light which is absorbed by it ; the lower one shows the same section photographed by the light, which it transmits in order to show detail (figs. 20 and 21).

The most important application of this method with which I am acquainted occurs in the photography of furniture, where the results are simply startling to the uninitiated. If a piece of reddish mahogany is photographed on an ordinary plate, no trace of grain is usually visible. The photograph is made by blue light to which both the red darker portions and the yellow light portions are black ; to give an increased exposure simply results in the photography of a plentiful crop of normally invisible scratches. If, however, a Panchromatic plate sensitive to the red is used, with a strong yellow screen, the results are entirely different ; the scratches disappear and the grain comes up in the most wonderful way ; in fact, so startling is the difference, that probably many of my readers will think that the illustration shown herewith is faked, but I can only assure them that, if they try the experiment, they will get similar results.

A useful example of this same principle of photographing in the coloured light which is reflected from the object, is given by the photography of prints for reproduction purposes. A warm sepia carbon print, for instance, if being copied for

photographic reproduction, represents a most difficult object, the shadows invariably clogging and the whole scale of contrast becoming greater, in spite of any variations of exposure or development. In the same way, a red silver print, when being photographed on wet plates for half-tone work, is well known as a most difficult subject, requiring usually a large amount of fine etching. These, and other cases of the same kind, can be dealt with very easily by using Panchromatic plates with a medium screen. The prints then become as easy to copy as any black-and-white subjects.

It must be noted that for this purpose the plate must be red sensitive, as red mahogany has a strong absorption in the greenish yellow of the ordinary isochromatic plate, and it may be well to remark again at this point, as at the beginning, that the whole of the discussion of this book is based on the use of plates that are panchromatic. Green-sensitive plates, however useful they may be for the amateur in landscape photography, may be ruled out when we are dealing with technical work, which requires us to work in any region of the spectrum which may be necessitated by the colour of our object.

Panchromatic Plate and Red Screen *Furniture and Negative by Maple, Ltd.*

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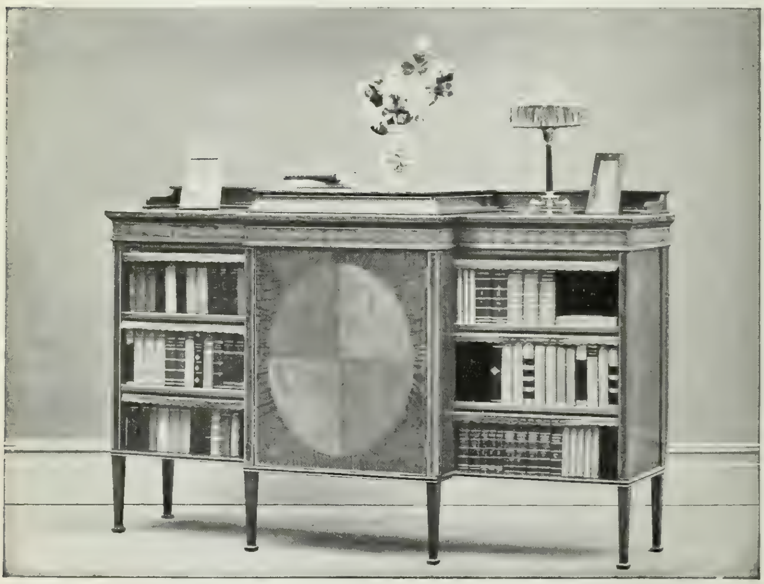
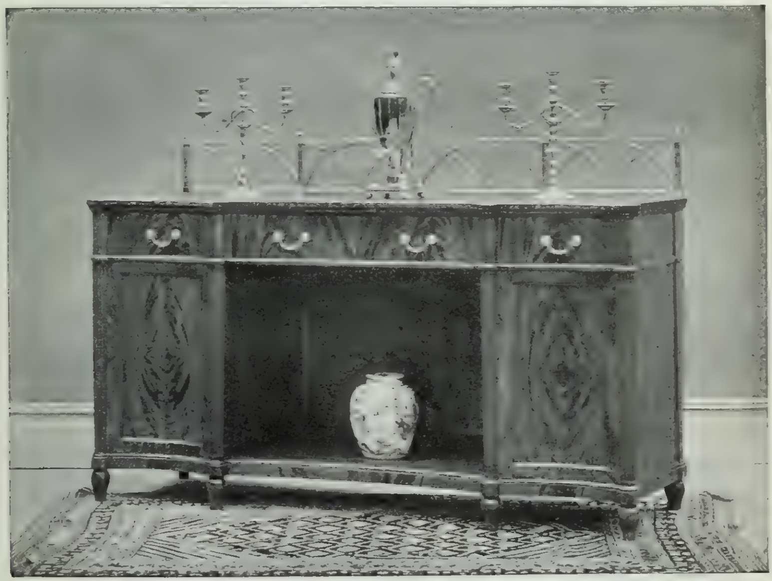
Iso Plate and Three Times Screen *Furniture and Negative by Maple, Ltd.*



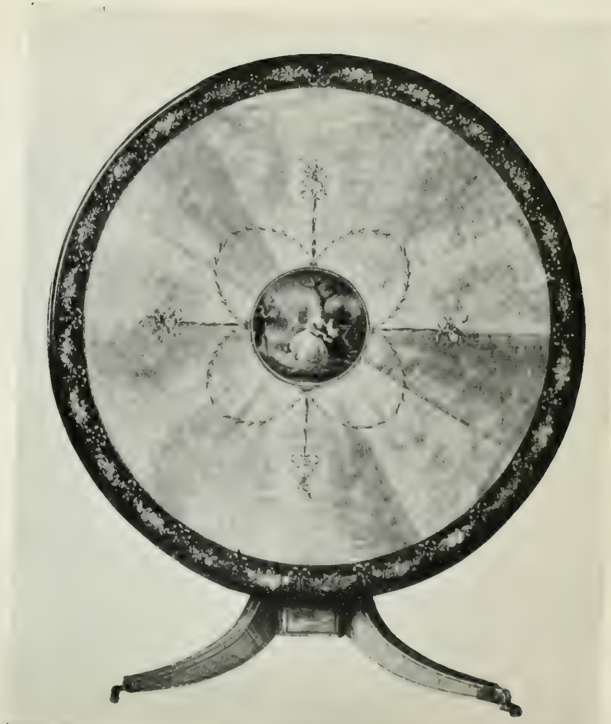
Panchromatic Plate and Red Screen *Furniture and Negative by Maple, Ltd.*

Ordinary Plate *Furniture and Negative by Maple, Ltd.*



Panchromatic Plate and Red Screen *Furniture and Negative by Maple, Ltd.*

rdin ary Plat:



Wratten Panchromatic Plate and Red Filter

CHAPTER V

PORTRAITURE

IN no branch of photography is the reproduction of coloured objects in correct monochrome of greater importance than in portraiture, and in no branch is it in greater danger of being ignored. The flesh tints, with which portrait photographers are mainly concerned, are chiefly of a reddish or yellowish nature, while the yellow and brown shades of the hair and the variety of the eye-colours, apart altogether from the clothing, cause every sitter to present a distinct problem in colour reproduction. Earnest efforts to meet this problem have been to some extent discouraged, by the assistance which the retoucher can give in correcting the errors introduced by incorrect colour-rendering. Retouching, however, is always a dubious remedy, and though expert artists may make good use of it, it leads to many pitfalls for most workers. We have only to look at a lantern slide, made from a retouched portrait and projected upon the screen, to realise how difficult it is for retouching to be satisfactorily applied. When making an ordinary enlargement it is often necessary to remove the whole of the retouching, so badly does it show. Even if the retoucher were able to satisfactorily lighten those parts of the flesh which the ordinary plate has failed to render with sufficient density, he would still be unable to darken these parts where the excess of sensitiveness to blue and violet has produced too heavy a deposit in the negative.

The rendering of colour in portraiture is governed by the same laws that govern the reproduction of colour in other subjects. Those who have studied the earlier chapters of this book will realise that photographing with ordinary

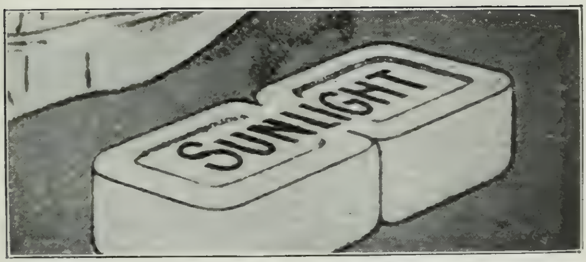
plates is equivalent to photographing by blue-violet light, to which alone such plates are sensitive. As blue-violet light is absorbed by flesh tints, the use of it produces an accentuation of contrast similar to that which always follows when any coloured object is viewed or photographed by light which is selectively absorbed by it. (See Chapter IV.)

Consequently portrait negatives taken upon ordinary plates are always more contrasty than the subject appears to the eye. To overcome this difficulty the subject may be either lighted with a softer, flatter light than would otherwise be used, or the negative may be over-exposed. But in either case accuracy of tone-rendering in all the portions of the picture which are *not* yellow or red is lost, and, to put it as it appears without analysis, the "lights" are degraded.

Not only is this general accentuation of contrast produced, but also the reproduction of the skin itself, which is really the fundamental work of the artist, suffers greatly from the contrast effect introduced by the use of plates insensitive to red. The illustration will possibly make this clear. The photograph of the bar of Sunlight Soap is enlarged from a lithographic advertisement in which the bar appears to be very faintly mottled in many colours; mostly brown and red. The grain is very small, and these brown and red spots being not only small, but alike in hue, are nearly invisible to the eye; so that in the original it appears smooth. When it is examined by violet light, however, the violet light is completely absorbed by the yellow, brown and red spots, and consequently, as was explained in our discussion of colour contrast, the contrast between these and the background is greatly increased. So that when the original is photographed on an ordinary plate a high degree of contrast is produced, and the photograph looks very mottled. Photographed upon a panchromatic plate with a K3 screen, we obtain an accurate reproduction of the lithograph, giving the same degree of smoothness as was apparent to the eye. This shows at once how any uneven stipple, such as this grain exhibits, produces this mottled, and to some extent woolly, appearance by colour contrast.

This exact effect is reproduced in photographing the skin. The surface of the skin is completely heterogeneous.

On Ordinary Plate



On Panchromatic Plate with K3 Screen

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On Ordinary Plate *Negative by Barraud*

On Panchromatic Plate with K3 Screen *Negative by Barraud*

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The small blood-vessels which cover it, and the pathological changes, which the failure of the pores of the skin to do their work perfectly produce with increase of age, make a sort of stipple of reddish spots and streaks over the whole surface of the skin.

This is very easily seen by examining any portion of the skin under the mercury vapour lamp. The light from the mercury vapour lamp consists for essential purposes of a mixture of green light and violet light, no red being present. The small red spots of the skin absorb very completely the green light from the mercury vapour lamp, but reflect to a considerable degree the violet ray, thus producing a general background of white light stippled over with violet spots. The same effect can be seen to a less extent by examining the skin through a green filter, when the mottling becomes much more marked than it is to the eye, but appears of course black, and not violet.

The same unfortunate contrast which produces this effect on the skin also accentuates wrinkles. Wrinkles are generally lined by small networks of capillaries, which have the practical effect of producing a red line on each side of the wrinkle. This, photographing black on the ordinary plate, greatly accentuates the depth of the wrinkle. The wrinkle at the side of the eyes is often deep red in colour, and consequently prints too dark when photographed by any but red sensitive plates, while the delicate violet shadows under the lower eyelid which give roundness and shape to the eye are seldom truthfully rendered with the ordinary plate, though when they do appear the retoucher generally removes them.

Sunburned freckles are of course yellow and, again completely absorbing the violet, appear as black spots. The two portraits of the lady reproduced were taken, the one on a Panchromatic plate with a K3 screen, and the other on an ordinary plate, exposures being given which render the background the same in the two cases. The accentuation of freckles and wrinkles with the ordinary plate is of course very marked, but on observing the skin texture, the point as to general smoothness will also be realised, though this is somewhat lost in the reduced reproduction.

An instance of the opposite fault to that of insufficiently recording red or yellow markings upon the plate, and thus accentuating their appearance, is shown by the way in which any bluish tinge produces too great a density and prints too light. The best example of this is possibly the mouth. The upper lip is usually a full scarlet and appears black in a photograph taken upon an ordinary plate, but in the lower lip there is much blue and violet, and it reproduces as unnaturally white, so that the mouth is often more like a quarter of an orange than a rose bud. Even painters, who ought to know better, copy this defect, when they have to paint a portrait from a photograph.

When dealing with the question of colour contrast, it was shown that while photographing in the absorption band of a colour produces contrast, photographing in the transmission band will produce an entire lack of contrast. Clearly, then, the deeper the filter we use, the smoother the result will become, and, indeed, if a portrait be taken through the red screen used in tricolour photography, the failure of contrast is so complete that the skin appears absolutely smooth, giving quite a false impression. There is, however, an application of this general principle of photography in the transmission band which we must next consider, and that is in the question of the hair.

This subject is of great importance to portraitists, because of the extreme difficulty in satisfactorily retouching hair.

Brown, golden, or red hair is always difficult to photograph, tending in the darker shades to produce black masses without detail. Golden hair is usually met by using a dark background (with a little paint on the back of the negative, as a correspondent ingenuously remarks), but this imposes a needless limitation, and will not meet the not infrequent case of a light golden brown moustache. Moreover, hair of these colours, even when exposure and lighting have produced a satisfactory *tint*, will always show absence of detail in the shadows. This is, of course, a parallel instance to the harsh contrast obtained when copying a warm brown or red print upon an ordinary plate. Photographing a sepia carbon, for instance, for reproduction work, produces a greatly increased scale of contrast, and quite empty shadows, a difficulty which can only be met by the use of red sensitive plates.

It may be as well to mention that even when panchromatic plates are used and the resultant negatives need no retouching in the ordinary sense of the term, the work of the artist is not finished. Indeed it is only when the negative is reasonably accurate that the retoucher can do his best work. People with snub noses, large ears, crooked teeth, crow's feet, or grey hairs, do not want to appear as they are, few of us do; but a retoucher should be an artist who improves the picture while preserving the spirit of the likeness, and not a mechanic who has to atone for the faults of the tools.

There is no need to dwell at length upon the effect of orthochromatic rendering upon the clothing of the sitter. To those who have carefully read the earlier portion of this book the advantages will be obvious. A point which may appeal to the professional photographer is that he will be able to free his sitter from any restraints as to the clothes which shall be worn. It is by no means an infrequent thing for a sitter to have a favourite costume, and to be disappointed at the difficulty which it presents to the operator.

But one point more may be mentioned, those photographers who tint their photographs will find that orthochromatic rendering is of the very greatest importance as enabling them to avoid masses of black where it is most important that they should have little deposit in their print, in order to get bright colours. To get a satisfactory coloured reproduction of a scarlet tunic, for instance, it is necessary that the negative shall have a good deposit of silver where the tunic is, so that the colour shall not be applied to a mass of black in the print.

Exposure.—The use of screens in portraiture raises obvious difficulties as to exposure. It is of these difficulties that I would speak next. Red sensitive plates can be obtained which are of the same speed as extra rapid plates, quite as fast as those generally used for studio work. For ordinary purposes, a K1 filter will be deep enough, and this will double the exposure. For difficult, badly freckled subjects, or such a case as the scarlet tunic, it will be necessary to use a K2 filter. Here the exposure will be about four times that to which the worker is accustomed. Each worker will know for himself whether he can manage this. At the

same time, I would point out the gain in rendering is so considerable, that it will justify the sacrifice of some accuracy in the lighting if that cannot be avoided. The improved rendering obtained by the use of the panchromatic plates also makes easier photography under conditions where complete control of the lighting cannot be obtained. Photography in ordinary rooms is often made far more difficult by the "unsuitable" colour of the surroundings, a difficulty which is, of course, eliminated by truly orthochromatic procedure. Even when the exposure is increased by the use of screens, it will be very much shorter than it was in the early days of photography, when wet plates were used. Then an exposure of five seconds was considered unusually short, and although we have no wish to return to the days of head-rests, yet, if we except young children, there are few people who cannot keep still in any position suggestive of repose for a much longer period than five seconds. And those photographers who have a preference for slow plates, and who have not used the rapid plates of to-day, will find the panchromatic plates, even when used with a K3 filter, as fast as those to which they have been accustomed.

Artificial Light Sources.—Artificial light sources contain as a rule much more red and green light than daylight. If we have two sources in which the blue-violet portions of the spectrum between 4000 and 5000 A.U. are equal in intensity, one being daylight, then, if the other be acetylene or metallic filament electric, the latter will give out seven times as much green and twenty times as much red light as daylight. If incandescent gas, it gives about twelve times as much green and fifteen to twenty times as much red. Enclosed arcs are similar to daylight, but if used with red or yellow flame carbons, the proportion is similar to acetylene. Open arcs have about one and a half times as much green, twice as much red.

Since we know the relative sensitiveness to blue, green, and red of the plates (Chapter II.), we can construct the following approximate table:

Light source compared with daylight, taking amount of blue-violet light as the same in the two sources.

Relative sensitiveness of the two plates as compared with an ordinary plate of the same sensitiveness to daylight.

Light Source.	Green Proportion.	Red Proportion.	Sensitiveness of Erythrosin Plate.	Sensitiveness of Wratten Panchromatic Plate.
Oil or carbon filament electric . . .	20	100	2	8
Acetylene or metallic filament (Osram) . .	7	20	$1\frac{1}{2}$	3
Incandescent gas . .	12	20	$1\frac{3}{4}$	4
Yellow flame arc . .	10	20	$1\frac{3}{4}$	4
Open arc . . .	$1\frac{1}{2}$	2	1	$1\frac{1}{2}$

It follows from this that, owing to the great sensitiveness of the panchromatic plate to the yellower artificial light sources, portraiture by their aid becomes easy. In an ordinary sitting-room, with one incandescent gaslight in the middle of the room, a sitter at six feet distance will require at F6 an exposure of about five seconds, an exposure which makes evening portraiture quite practicable. Street work at night, and theatre photography, become also much easier if red sensitive plates are used. For incandescent gas no screen is used, the colour of the light ensuring sufficient correction, but if arcs are used (with flaming carbons) a K2 screen should be used, owing to the very strong ultra-violet and violet carbon bands which must be absorbed.

Very good work can be done with such a lamp as the Boardman Arc, with a K2 filter and exposures of about five seconds at F6.

The Mercury vapour lamp is not suitable for work with panchromatic plates. It does not emit any appreciable amount of red light, and its value for photographic purposes depends upon the violet light which it gives out.

CHAPTER VI

The Photography of Coloured Objects for Reproduction

THE photographer for reproduction will have many objects to photograph similar to those which have previously been dealt with, and the procedure will, in the main, be similar. It will be convenient to consider for what process the negative is required before deciding on its character. If it is to be merely an ordinary photographic copy in monochrome of a coloured object, then the usual rules apply—a negative of good contrast for carbon, as free as possible from fog for platinum, of softer gradation for bromide, and so on. If the negative is required for mechanical printing, then we must know the process, *i.e.* whether for a surface process, such as lithography and collotype; intaglio, such as photogravure; or relief, such as half-tone.

Photography is sometimes brought to the aid of pure chromo-lithography, when the reproduction is to be of a different size from the original, or if it is framed, and cannot conveniently be used otherwise. The first thing necessary in the process is to make a key tracing, which is an outline made on transparent transfer paper, of every patch of colour showing variation from the next patch. This has to be transferred on to all the stones used to build up the coloured picture, in order that the artist may know exactly where to put his work, so that in the end the "register" or fit of the various colours is perfect. If now a photograph must be used instead of the original itself, it is obvious that a negative must be made which best distinguishes the variations of colour, and that the correctness or otherwise of their

translation into monochrome is of no importance whatever. The plate used and filter chosen must therefore depend entirely on the character of the subject, having this end in view. Viewing the original through a number of differently coloured filters will frequently be of assistance. It will sometimes be found that an ordinary plate, without any filter at all, will distinguish the patches of colour better than any other procedure. With regard to collotype and photogravure, which require ordinary negatives, colour-sensitive plates with contrast or compensating filters should be used, as the particular subject requires.

Now, with regard to photo-lithography and relief processes, in which the final result is to be a surface broken up into grain, the grain is nearly always required in the negative from which the copying on to the printing surface is done. Consequently it is an economy if the negative, which gives us the colour record, can also be split up into grain at the same time. To work in this manner is called the "direct process," and the Wratten Process Panchromatic plates are specially designed for this purpose. Whether it is possible to work "direct" or not depends on the amount of contrast contained in the original.

In a grained negative the illusion of tone is secured, not by varying density (*i.e.* thickness of deposit of silver), as in an ordinary continuous tone negative, but by deposits of silver in the form of spots of very great opacity, but of varying size. Places where the spots are very small and there is much clear glass will represent shadow, those where the spots are very large and there is little clear glass will represent the high lights, and proportionately for other tones; the size of the dots everywhere corresponding to the amount of light reflected from the original. Any given area in the high lights must contain some transparent space, and in the shadows must contain some points of dense silver. But it is obvious that, if there is a considerable amount of contrast, it will be impossible to fulfil the necessary conditions, because before any points of silver have impressed themselves in the shadows of the negative, the dots in the high lights will have received so much exposure as to make them completely cover up all the transparent spaces, and that part will no longer serve as a grained negative. So

that only certain objects or originals are suitable for reproduction by the "direct" manner, which consists in placing the object in front of the camera, illuminating it, and photographing with the half-tone cross line or irregular grain screen in front of the plate. The actual details of this work would be out of place here; further details can be obtained from the booklet on "Reproduction Work with Dry Plates," published by Messrs. Wratten & Wainwright, Ltd. It may, however, be well to point out that originals with heavier contrasts than about sixteen to one should not be attempted; that is, if the light reflected from the shadows is taken as one, then that reflected from the high lights should not be more than sixteen times as much. It is true that heavier contrasts are often done, and made to pass by the waving of white paper in front of the original during the exposure, a practice known technically as "flashing," but, beyond a small amount, this practice is very strongly to be deprecated, as it is ruinous to detail and gradation, and plates and filters must not be blamed if the results appear flat and unsharp when this is done.

With subjects of heavy contrast resort must be had to the "indirect" process. In this a negative is made in the ordinary way, but the exposure and development are so arranged that, while all the detail is secured, the density of silver deposit is restricted, so that the negative does not exceed a certain range of contrast. From the negative a positive is made, either on paper or, preferably, on a slow dry plate (*i.e.* a transparency). This, while having all the detail of the original, will have the contrasts compressed so that they are within the limits possible to the half-tone process, and a grained negative can now easily be made in the usual manner, either on the wet collodion or on another dry plate.

Now, as examples of common subjects having heavy contrasts, we may take most solid objects such as articles of furniture, carpets, etc.; though some articles for catalogue illustration, such, for example, as sweets or packets of soap, may very well be done direct. Many oil paintings, especially old ones, are better reproduced by the indirect process.

The next thing to be considered is the style of reproduction. If for monochrome printing, then the principles

already outlined in previous chapters must be applied. If colour contrast is required, then a filter must be used absorbing that colour which it is appropriate to render darkest, and a plate sensitive to the colours that are not required to print. If, on the other hand, correct luminosity values are wanted, then a K2 or K3 filter should be used with a panchromatic plate. In general it will be found that, for colour-work in a reproduction studio, the panchromatic plate will be most suitable; for "direct" grain negatives, the process panchromatic.

The simplest cases of colour reproduction are presented by stained MSS., typewriting, cheques, maps, and so forth. These nearly all require the use of contrast filters. A full discussion on the correct procedure will be found in Chapter IV.

Next come subjects to be reproduced in two colours. Sometimes these are drawn in two colours, sometimes in more; in either case it is desirable to know what coloured inks are to be used in the reproduction. Filters are then selected so that the light reflected from the parts of the original which it is desired to print in one of the inks shall be absorbed so that the negative is transparent there. Thus, supposing we have a crayon drawing of a lady's head in pink and yellow, we want a green filter to absorb the pink and allow the yellow to pass, and a blue-violet to pass the pink and absorb the yellow. Many good colour-effects may be obtained in two printings when the two inks together make a black. Any two inks of colour complementary to each other will give a black and scale of greys, as well as the two colours separately. Thus, an orange-red and a greenish-blue will give those two colours and black; a green and pink, the same; an ultramarine, a blue and a yellow. This method can be applied, also, when we only have one colour and black; for example, a red and black. The use of the red filter, A, and a panchromatic plate will permit only the black to be photographed; the second negative is made with a blue filter, and will give us both the red and black. Now if this be printed in an ink imitating the red of the drawing, the black can be printed in black, or in an ink which on the top of the red will make a black. Another method is to make a positive from the negative taken through the red

filter; now register upon this the negative taken through the blue filter.

This latter negative records both blacks and reds as clear spaces, while the positive records only reds as clear spaces, so that the two together are equivalent to the red negative. The black negative is, of course, taken through the red filter. If we have several colours and black the procedure is more difficult, and it is sometimes troublesome to extract the black if the colours are at all dark. A filter should be selected that does not completely cut out any colour present, but that transmits most freely the deepest colour. Sometimes it is most convenient to expose the same plate for a portion of the time through each of the filters of a tricolour set, but the filters have to be very good ones, as otherwise the resulting image will appear doubled (see Chapter IV.). Sometimes, on the other hand, no filter at all is necessary, or at most a light yellow filter and a sufficiently long exposure will give the black alone on the negative.

It is unnecessary to deal with the three-colour process here, as a chapter is devoted to that by itself, and the methods are exactly the same in a reproduction studio, except that arc lamps are frequently substituted for daylight. These, however, of whatever type, do not cause any other adjustment than corrections in the exposure ratio of the filters, which will not be the same as for daylight.

It is yet far from being realised how much help could be obtained from intelligent photography in photo-lithography. The use of the camera, with suitable plates and filters, could save much artists' work, if the possibilities were realised. We have seen beautiful reproductions of water-colours by photo-lithography where the artist has had a photographic basis on the stone, and these were produced in days, where otherwise weeks would be required. Though the reproductions we speak of have been made in from five to ten printings, the perfection of the plates and filters now obtainable, if used with knowledge, would enable excellent reproductions to be made with very few printings, and this question is worthy of the serious attention of all chromo-lithographers. The increasing popularity of Off-set work gives many opportunities for the use of photography in preparing the printing surface, and a knowledge of the

possibilities in making negatives of coloured originals is very desirable in order that full advantage may be taken of the process in the most economical manner.

The same is also true of Rotary Photogravure, which must sooner or later be applied in a large way to the reproduction of coloured subjects.

Negative on Wratten Panchromatic Plate *By W. T. Greatbatch*

A Meadow

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CHAPTER VII

Landscape Photography

THE application of the principles, which have been set down in the earlier chapters of this book, to the photography of landscapes, presents difficulties of which most workers are only too well aware. The discussions which follow papers on "Orthochromatism" in photographic societies usually turn on these difficulties, and the variety of conflicting opinions expressed should be sufficient warning to prevent any writer, and especially one whose experience in practical landscape photography is small, from too dogmatically stating what should be done. It may be interesting, before explaining what seems to me to be the bearing of the general principles of colour reproduction upon landscape work, to mention some of the conclusions to which various friends of mine, with much experience in landscape work, have come.

Mr. W. R. Bland, who is justly known for his beautiful landscape work, with far-reaching vistas of valley and hill, says that he "thinks colour correction unnecessary, as a non-colour plate will give the more simplified rendering, and will more easily render atmosphere."

On the other hand, Mr. Greatbatch is a strong believer in the use of fully corrected orthochromatic plates.

To M. André Callier, a Belgian worker, who is both a first-rate landscape photographer and a scientific investigator of great knowledge, I am indebted for the framework of this chapter, and for many of the points with which I deal, as well as for the Alpine photographs which he has allowed me to reproduce.

M. Callier considers that red sensitive plates with a variety of correcting screens are necessary for general landscape

work, and that, especially in Alpine photography, a deep over-correcting screen is frequently of use.

Mr. S. H. Wratten, who has sat out a great number of club discussions, thinks that the tendency among advanced landscape workers is towards a highly colour-sensitive plate, and a slightly correcting screen, probably only doubling the exposure.

Landscape photography presents several features which entirely distinguish it from those branches of work with which the rest of this book is concerned. In the first place, landscapes display, as a rule, in our northern climates a less marked scale of contrast than the subjects with which we are accustomed to deal in the studio. At the same time, however, the sky is usually of much greater intensity than any other portion of the gradation scale, and it follows that, in order to obtain detail in the shadows (seen by the eye because of the expansion of the iris), it is often necessary to over-expose the sky.

This over-exposure, which destroys differences in intensity which are perceived by the eye (clouds for instance), can be removed by the use of contrast colour screens, which, by absorbing the sky light, *seem*, in certain cases, to lengthen the scale of intensities which the plate is capable of rendering.

It is desirable to point out that, if such deep screens be employed, it is absolutely necessary that the exposure should be ample.

Insufficient exposure will result in a thin sky in the negative, and in general hardness in the foreground, and the resulting picture will give a general impression of *over-correction.*

True, over-correction in landscape work is, I believe, very rare ; it may, of course, be caused by the deliberate use of very strong yellow screens (and on this point it may be well to add a reminder that, as explained in Chapter III., screens which are necessary with a slightly colour-sensitive plate may over-correct a panchromatic plate), but as a general rule, the appearance of over-correction is caused by under-exposure.

The aim of many landscape photographers is simply to get the clouds and landscape on the same plate. Comparatively small correction is sufficient to accomplish this, and hence

the majority of such photographers use a very light screen, such as the K1, which, with a panchromatic plate, will give enough correction for the purpose given above, and at the same time enable the camera to be used in the hand.

But those workers to whom truth of tone is of the first importance will desire to use screens of greater depth, so that the colour values of the foreground shall be correctly translated into monochrome.

Many such workers use comparatively deep screens with plates sensitive to the yellow-green, but not to red, arguing that few landscapes contain red, or even yellow, and that the greens can be satisfactorily rendered by a green sensitive plate. On this point the following quotation from a letter from M. Callier may be of interest:

"It is necessary to insist upon the kind of orthochromatic plates which may be used. In spite of the enormous progress realised by plates of the erythrosin type, such plates show a grave defect in their lack of sensitiveness near W.L. 5000." (See fig. 10.)

"Usually this defect is not of great importance, but there are certain cases where it becomes a great disadvantage. This is so in landscapes, for example, which contain both open meadows and pine trees. If such subjects are photographed by means of plates of the erythrosin type (especially with a screen, if there is also distance to be rendered), there will be obtained in the negative a greatly exaggerated contrast between the densities of the meadows and of the pine trees. The green reflected by the meadows corresponds to the maximum of sensitiveness of an erythrosin plate, while that coming from the pines falls exactly into the gap of sensitiveness. The only method of obviating this is to use a really compensating screen—that is, a screen which absorbs the violet and ultra-violet, but which also has an absorption about the region 5600 corresponding to the maximum of sensitiveness of an erythrosin plate. Unfortunately, the increase of exposure required by such a screen is very great.

"From this standpoint the new isocyanin sensitisers represent a great advance over erythrosin. Used with a screen absorbing only the blue, violet, and ultra-violet, these new plates give the same results with an exposure factor of 5.

Of course the fact that these plates are sensitive to the orange and red constitutes a second advantage whenever red enters into a landscape."

An important factor in landscape photography which does not enter into studio work is the presence of water particles suspended in the air, which, when of large size, condense into mist. It is well known that a very slight amount of mist results in flat negatives, if open landscapes are being photographed, unless strongly corrected orthochromatic plates be used.

The reason seems to be that the suspended particles of water vapour which are transparent for the longer waves of light, and, therefore, only affect vision slightly, act as a very turbid medium for the deep violet and ultra-violet waves, scattering them, and producing much the effect that would be seen if one were to try and look through a sheet of finely ground glass.

As the water vapour condenses, its selection of the longer wave lengths increases; a fog, for instance, will absorb the blue and green rays from the light of an arc-lamp, but will permit the red to pass in greater measure, so that at a little distance the lamp will appear red.

M. Callier suggests that mist plays the part "of a screen whose maximum of transparency is in the ultra-violet, and of which the opacity grows regularly as we pass towards the red in the spectrum." He points out the similarity between blue skies and bluish distances and the consequent high reflecting power of mist for violet and ultra-violet light; while, as Spring has suggested, it is possible that the colour of the upper air is due to its own intrinsic colour and not to scattering.

It seems to me more probable that the *scattering* of mist near the ground is at a maximum in the ultra-violet, and that this *scattering* decreases as we pass towards the red.

In order to remove this increased effect of mist in the negative, as compared with the effect seen by the eye, we must remove the scattered ultra-violet and violet light by means of a screen. It is to be noted that, to be effective, this screen must absorb the ultra-violet as completely as possible, and that screens made of such dyes as filter yellow K are, therefore, preferable to even much deeper

screens made of such dyes as tartrazin, which transmit ultra-violet light.

The removal of the scattering effect of mist will progressively increase as we remove the violet, blue, and greenish blue, by means of deeper and deeper screens, so that, if strong sharp-cut screens be used, the air will appear too transparent —that is, there will be a loss of "atmosphere." It is, therefore, important that the screen should be of gradual cut, corresponding in curve to the sensitiveness of the eye, and that sharp cut, strong screens should be avoided. In telephoto work, however, the mist intervening in the great aerial distances between the lens and the object to be photographed, is a very serious and real difficulty, and a strong contrast screen, such as Wratten G screen, is a great advantage. Many telephoto workers who are troubled by the flatness and fogginess of their negatives would gain much by the use—first, of a satisfactory lens hood cutting off all light not required; and, secondly, of a strong contrast screen.

It may be remarked that the screen used for telephoto work must either be plain uncemented gelatin, or must be cemented in the very best optical Flats. The great equivalent focal lengths of the lenses employed will not permit of the use of ordinary screens if the best definition is to be obtained. The most convenient method of employing the screen is usually as a cap on the back of the negative lens, inside the camera, which position enables one to employ the smallest possible screen.

While dealing with telephoto work, I may point out that most landscape workers could take a hint from the telephotographer with regard to *hoods*.

Modern anastigmatic lenses are made to work at such great angles that they are never fitted with hoods at all, and the inevitable result is *flare*. Landscape workers, who do not, or at any rate should not, employ wide-angle lenses, should fit one or more hoods to their lenses, and they will at once see the gain in their negatives.

Flat and foggy negatives are due to

(1) Flare, removed by a proper hood;
(2) Mist, removed by a proper plate and screen;
and rarely (3) Over-exposure.

Alpine work presents a few special difficulties. Great distances are continually occurring in consequence of the purity of atmosphere, and the chief difficulty consists in retaining correct gradation between the sky and the snow-clad peaks outlined against it.

The light of the sky is due to the numberless dust and water particles suspended in the upper air. The greater reflecting power of these small particles for violet and ultra-violet light causes the sky colour to be blue, and as we ascend higher into the air the particles decrease in size, and the sky reflection becomes less, so that the colour becomes a deep blue, and at very great heights the sky is nearly black. An alternative suggested by Prof. Spring is possible, namely, that the colour of air, and especially the upper air, containing much ozone, is blue, and that the upper air absorbs the red light from the white light reflected from suspended particles.

If, therefore, a deep or even medium screen is used, it may happen that the sky light may be cut out too completely, and the sky will appear too dark, with the intensely white snow showing in great contrast against it. It is of course true that this is to a great extent also the effect to the eye, and that a truthful rendering is simply displeasing when the charm of the sky colour is removed, but the effect is certainly exaggerated if the screen used is of too sharp cut.

For ordinary Alpine work, a K1 screen is of sufficient depth to satisfactorily render both sky and pines against the snow. For Alpine telephoto work, a K2 screen is necessary to remove the haze, a G screen being too strong if the distances are free from fog.

The nature of the reflection of the sky also gives us a clue as to the best means of rendering cloud forms. It is clear that the rendering of cloud form depends on causing the cloud to have the maximum effect on the plate when contrasted with the light reflected from the sky. Since the light reflected from the clouds is white, while that from the sky contains a lesser proportion of the longer wave lengths, it is clear that the deeper the screen the greater will be the contrast. Thus the use of an ordinary plate, photographing by means of the violet and ultra-violet light, will usually obliterate the contrast, unless the clouds be very strong. Using a panchromatic plate and a K3 screen, we shall

Telephoto, Wratten Colour Sensitive Plate — *A. Callier*

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Wratten Colour-Sensitive Plate *A. Callier*

p. 55]

obtain the same degree of contrast as that which is seen by the eye.

With the strong yellow G screen this contrast will be exaggerated, while with the tricolour A screen we get a very high degree of contrast, making this screen probably the most useful one for the record of faint cloud forms. By the use of an even deeper screen, such as is obtained by using the D and G screens together—with a special plate such as the "Wratten Spectrum Panchromatic," or a plate bathed in dicyanin—we can photograph near the limit of the visible red, and owing to the small proportion of this light reflected by the sky, can record wisps of vapour which are barely visible to the eye.

CHAPTER VIII

Three-Colour Photography

(1) THE ADDITIVE PROCESS

THREE-COLOUR photography is based on the fact, first discovered by Clerk Maxwell in 1860, that all colours can be matched by a mixture of three primary colours —a red, a pure green, and a blue—if the proportion of these constituent colours be rightly chosen. By an apparatus which he termed the "Colour Box," Maxwell determined the exact position in the spectrum of these three primary colours, and also the proportion in which, at each point of the spectrum, they must be mixed in order to reproduce to the eye the sensation produced by the light of the spectrum itself. The intensities of the primaries at each point form three overlapping spectral curves, which are shown in the figure (fig. 22). If, now, we construct a set of three filters which, when used with a suitable plate, will give these curves, we can obtain in the spectrograph a set of negatives in which the opacities at every point of the spectrum are proportional to the light intensities for each primary. If we make from these negatives transparencies, and project the three transparencies so that they converge upon one screen by means of approximately monochromatic lights exactly corresponding to the primaries, we shall reproduce the spectrum ; or rather, we *should* reproduce the spectrum if our plates would rigidly translate light intensity into the equivalent opacity. This they will not quite do ; at the same time the reproduction is very good. This result, however, can only be obtained if the correct exposure is given to the spectrum. If a number

of varying exposures to the spectrum be given, it will be found that the reproduction will vary, not in intensity only, but also in colour. The reason can easily be seen by referring to the diagram (fig. 22) showing the curves of the filters. Take, for instance, the point 6100, which should be recorded to the fullest possible extent in the red filter, and to about $\frac{1}{3}$ of the possible extent in the green filter, and should therefore be reproduced by the whole of the red light, and by $\frac{1}{3}$ of the green, thus appearing orange. With the shortest exposure, however, this will record only in the red filter, and not at all in the green; that is, it will be projected as a faint but pure red. On the other hand, with great exposure the plate will be quite opaque in both the red

Tricolour Sensation Curves

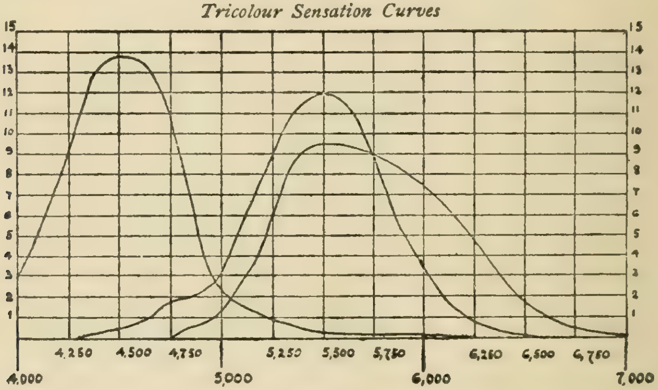

Fig. 22

and the green negatives, and in reproduction we shall have a bright yellow caused by the mixture of all the red with all the green. The same is true of nearly all points in the spectrum. With over-exposure the region about 5200, for instance, which should be pure green, will be recorded to some extent in all three filters, and will reproduce as a greenish white. This variation of colour with exposure is of great importance in practical photography, as whatever variation there is in intensity, the true *hue* must always be reproduced. It is consequently necessary that the absorption curves of the filters should be as abrupt as possible, and, as a matter of fact, suitable filters are shown in fig. 23.

Such filters will not satisfactorily reproduce the spectrum; they will divide it into five sharp and abrupt regions.

First, the region extending down to 6000, which has been recorded in the red filter only, and which is therefore reproduced as pure red. Secondly, the narrow region between 5900 and 6000, which has been recorded through both the red and the green filters, and which, therefore, reproduces as a mixture of red and green light, that is, as yellow. Thirdly, the region between 5900 and 5000, which is recorded only in the green filter, and reproduces as green. Fourthly, the region between 4800 and 5000, recorded in both the green and blue filters, and reproduced as blue-green. Fifthly, the region between 4800 and 4000, recorded only in the blue filter, and reproduced as blue.

It will be noticed that this failure is only in the reproduction of pure colours other than the projecting colours themselves and their simple mixtures. In natural

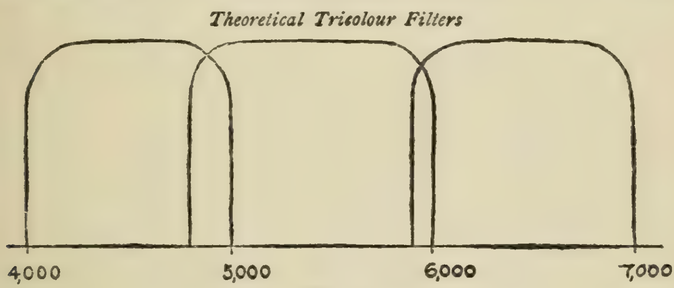

Fig. 23

objects such pure colours do not occur. In the spectrum, for instance, a green of wave length 5600 is a yellowish green, while a green of wave length 5200 is a bluish green. Both will reproduce alike with sharp-cut filters, since both will be recorded only in the green filter. The yellowish green of any object will, however, be recorded fully in the green filter, and to a less extent in the red filter, while it will only record to a very slight extent in the blue filter. It will, therefore, reproduce as a yellowish green. A natural blue-green, on the other hand, will be recorded to but a very small extent through the red filter, and to a much larger extent through the blue filter, so that it will reproduce as a blue-green. The illustrations show the absorption curves of dyes made up to exactly match to the eye the spectral regions (fig. 24).

The transparencies made from the negatives taken through the three filters can be projected, either by means of a triple lantern or by such a device as the photochromoscope. The filters to be used for projection are somewhat different both from the taking filters and also from the original narrow bands which we have hitherto assumed.

In projection with the triple lantern, especially, the great difficulty is to obtain sufficient light, and this difficulty at once prohibits any approach to monochromatic illumination. In order to get bright colours, it is necessary that the

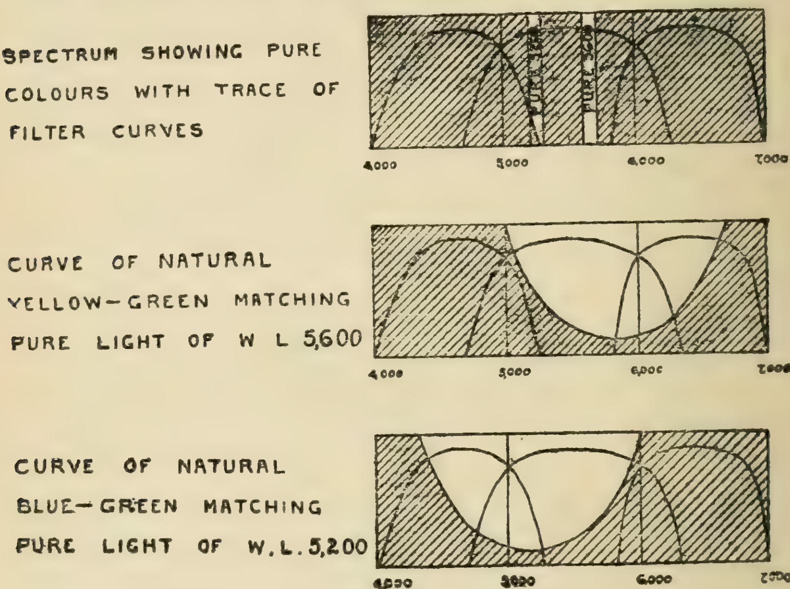

Fig. 24

absorptions of the projecting filters should be abrupt, and that they should not appreciably overlap one another. Inasmuch as the taking filters do somewhat overlap, it is better to use a different set for purposes of projection. The red projecting filter should be a true, strong red, not an orange—that is to say, it must not pass any light of shorter wave length than 6000 A.U. The green should be a pure green, not transmitting any blue, and extending from 6000 to 5000 A.U. It would seem that the taking blue filter should be suitable also for projecting; if, however, the triple lantern be set up, and

the above-described red and green filters be used, together with standard blue, it will probably be found that the field is yellow. This is due to the fact that dyes absorb some of the light which they are supposed to transmit, and the proportion which they absorb depends on the dye (see Chapter I.). Owing to the fact that absorption bands are nearly always sharper towards the red end of the spectrum than towards the blue end, a red filter will absorb very little red light. Our red filter absorbs, at 6400, 16 per cent. of the incident light. A green filter absorbs much more green light; at 5900 our green filter absorbs 74·3 per cent., transmitting only about a quarter. At 5400 it transmits about half the incident light. But a blue filter absorbs very much blue light. At 4800 our blue filter transmits about one-fifth of the light, and the same proportion at 4500. This absorption of useful light by the blue filter is not a disadvantage in photographic work, because, even with the best red-sensitive plates, the exposure through the red filter is considerably greater than that through the blue filter, and if the blue filter were lighter, the effect on the total exposure would be inconsiderable, while the exposure through the blue filter would be so short that it would be more difficult to give it accurately. But this absorption of the blue light by the blue filter is a serious disadvantage if the filter is used in tricolour projection and it is therefore necessary to use the brightest blue filter which can be obtained.

This additive synthesis, as it is called, by means of a photochromoscope or triple lantern, is much the easiest process of three-colour photography to work, and gives also the best and most accurate reproduction of coloured objects. A modification which has recently greatly developed is the screen-plate method of colour photography. In this method, suggested by Ducos du Hauron, and first carried out by Joly, a glass plate is divided into a number of coloured elements, these elements being so small that they are indistinguishable to the eye, and being coloured with the three primary screen colours, so that the plate as a whole appears to be grey. Such a plate is put with the elements in contact with the film of a panchromatic plate, which has been so adjusted to the screen, either by means of modification in the making of a plate or by a compensating filter, that white light produces equal effect through each of the three colour elements.

If a negative of a coloured object be taken on the plate through such a screen, and a positive be made from the negative, this positive being registered again upon the same screen, we shall obtain a reproduction of the coloured object by additive synthesis.

Thus, in the diagram, fig. 25, we have three patches of red, green, and yellow light falling upon the screen, which is represented only by three unit elements. The red light penetrates the red elements, producing blackness in the negative film beneath them. The green light penetrates the green elements, producing blackness in the film beneath them. The yellow light, composed, of course, of a mixture

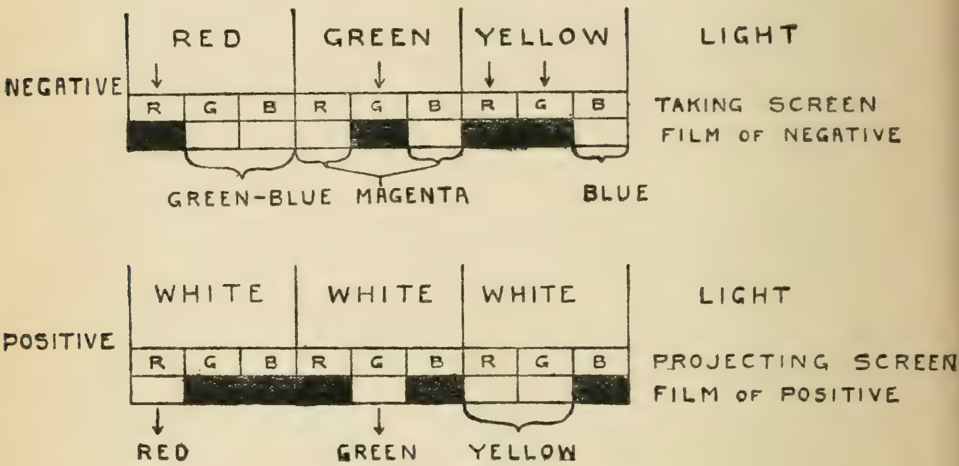

Fig. 25

of red light and green light, penetrates both these elements, leaving the negative film transparent only under the blue elements. When the positive is registered again upon the screen, the red light is represented by the clear red elements, the green and blue ones being obstructed. In the same way the green is represented by clear green elements, the red and blue being obstructed, and the yellow is represented by the light coming from the mixed red and green elements, the blue only being obstructed. It will be seen that if the negative instead of the positive be registered upon the screen, the complementaries to the original colours will be obtained ; the red will be represented by a mixture of green

and blue, the green by the magenta colour resulting by mixing the red and blue, and the yellow by blue.

Professor Joly, who used exactly the method described, made his taking screen of wide-banded colours somewhat resembling the colour mixture curves, while the viewing screen on which the positive was registered had deep narrow-banded colours.

The Lumière Autochrome plate, on the other hand, is not worked in quite the same way. The colour elements in this are very small, being composed of flattened starch grains, and the emulsion is coated on the plates. After exposure and development the image in the emulsion is reversed, so that it is converted into a positive and the colours can be seen at once.

This necessitates the use of the same filters for taking and viewing, these filters dividing the spectrum almost exactly into three equal parts. The exactness of colour-representation of the Lumière Plate would seem to justify such a procedure, though undoubtedly pure deep reds would be better rendered, if a less orange red could be used for the viewing filter.

There are many systems of screen-plate photography, though none except the Lumière Autochrome plate are as yet actually in general use ; for a general theoretical discussion of the subject the writer's lecture to the Society of Arts published in the *Journal of the Society of Arts*, vol. lvi., p. 195, may be consulted. For practical instruction there are several excellent handbooks, and numberless articles dealing with the matter.

(2) THE SUBTRACTIVE PROCESS

The Additive methods of Synthesis give results of great accuracy and are very easy to work, but there are several defects connected with them. Probably the greatest is the difficulty of obtaining bright pictures.

The triple lantern is wasteful of light and is also a very expensive piece of apparatus. Screen plates can, at best, only give one-third of the brightness which should be given by their whole surface, and they therefore require powerful light sources to show them satisfactorily. Another defect is

that the additive processes cannot give paper prints, at any rate as yet. For these reasons the subtractive processes are of more practical importance than the additive, and though the introduction of commercial screen-plates has greatly increased the use of additive methods, the fact that the subtractive process is used in commercial three-colour half-tone work makes it much the most widely used method.

In subtractive processes the three negatives, through the red, green, and blue filters, are taken as in the additive process, but they are printed, not as transparencies to be projected by coloured light, but as three superposed prints, each print being made in a colour which is complementary to that of the taking filter.

Thus, if we divide the spectrum so that we consider white light to be made up of red, green, and blue; then the negative taken by red light is printed in a colour which transmits all the green and all the blue, simply absorbing the red. In the same way the negative taken by green light is printed in a magenta colour, which transmits all the red and all the blue, absorbing the green. The negative taken by blue light is printed in yellow, which transmits all the red and all the green, but absorbs the blue. Let us turn now to the fig. 26, which shows six patches of colour consisting in the top line of red, green, and blue, and in the bottom of their complementaries, blue-green, magenta, and yellow. In the red negative we shall record as black the red patch, and also the magenta and yellow patches, by virtue of the red light reflected from them. If we print this in a blue-green ink we shall print blue-green wherever there was no red in the original; that is to say, in the position of the green patch, the pure blue patch, and the blue-green or minus red patch.

The green negative will record as black the green patch, and the green-blue and yellow patches by virtue of the green light reflected from them. Printing it in magenta we shall print magenta ink in the positions of the red patch, the pure blue patch, and the magenta patch, these being the patches from which no green light was reflected. In the same way the blue-filter negative will record as black those patches from which blue light is reflected; that is, the blue patches, and the magenta and blue-green patches. This is printed

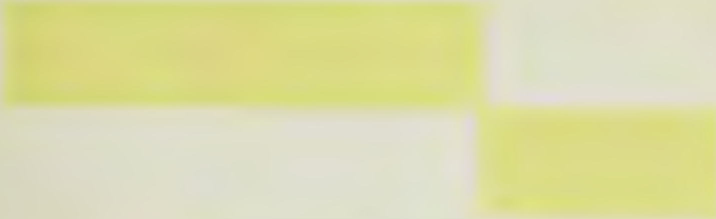

Fig. 26

a yellow ink, so that we print yellow in the places where no blue is reflected ; that is, in the positions of the red patch, the green patch, and the yellow patch. Superposing these three printings, as is done in the original figure, we obtain red by the printing of magenta ink upon yellow ink, green by the printing of the green-blue ink on the yellow ink, and blue by the printing of the green-blue ink upon the magenta ink, the other three patches being produced by the printing of the three inks separately. If we print all three inks on the top of one another we shall get a black, or if they are only partially printed a scale of greys. Of the various methods for actually preparing photographic lantern slides or prints in the three-colour process I do not intend to speak in this book ; for that purpose reference should be made to a book on three-colour photography such as Dr. König's book on "Natural Colour Photography," translated by Mr. E. J. Wall, but it is necessary to discuss the filters, plates, and printing colours.

The question as to the filters to be used in the subtractive process, with especial reference to half-tone work, was investigated by Mr. A. J. Newton and Mr. A. J. Bull (*Phot. Journ.*, October 1904).

They come to the following conclusions:

1. It is not possible, nor is it desirable, for any filter and plate to follow either the colour sensation, colour mixture, or certain other calculated curves.

2. The effect of using plates having maxima, with broad-banded weak filters, is to cause a degradation of any pure colour occurring in the band of insensibility, therefore plates showing gaps in the spectrum record (erythrosin plates), *e.g.*, should not be used for the green negative.

3. Ultra-violet should not be recorded, as it will exercise a disturbing effect where it is recorded by colours other than blues and violets, as is the case with some browns, scarlets, and yellows, these reproducing with a distinct bluish tint.

4. As much red should be recorded as possible.

5. There should be no unrecorded gaps in the visible pectrum, for while these may not be important for certain mixed colours of pale tints, they are fatal to correct rendering of colours whose spectra do not extend beyond the gap.

6. We think that we have proved that the filter records

should be even, end abruptly, and overlap each other as follows : the blue-violet and the green should overlap from 4600 as far as 5000, and the red and green should overlap from 5800 to 6000.

These recommendations as to the filter transmissions appear to be sound, and form a sort of mean to the practice of various workers. The crux of the whole matter lies in the question of the green filter. According to the theory of the subtractive process, pure blues are produced by the printing of magenta on blue-green, the absorption of the green leaving blue. Unfortunately most magenta inks, and indeed most dyes, absorb far too much blue, and when printed on blue-green they leave only a very dark and violet blue.

In order to avoid this it is desirable to prevent full-strength magenta being printed on the blue-green by recording the blue to some extent in the green filter negative. Unfortunately the extension of the green filter, in order to allow this, involves a difficulty with green, and especially with dark and yellow greens.

The exposure which is given to the green filter is regulated, not by the light reflected from *greens*, but by the light reflected from *white* objects.

Now, as has been shown in Chapter I., green objects show a considerable absorption of the green light itself, and consequently if the green filter is broader than their region of strong reflection, green objects will appear very dark and be much under-exposed. The result of this will be that some magenta will be printed on the greens. Moreover, the green-blue ink or dye very rarely contains sufficient green, so that greens are usually too dark, and the effect of the printing of a small quantity of magenta is very serious.

It is necessary to compromise, and probably the best effect is got by a green filter which is somewhat narrower than that suggested by Newton and Bull. The Wratten tricolour green filter extends from 6000 to 4800. With modern red-sensitive plates it is necessary that the green filter should not have any appreciable extension into the red. Red colours are usually very luminous, absorbing little red light, and if they are transmitted by the green filters they will record, preventing the printing of sufficient magenta, and making the resulting colour too orange.

This great luminosity of red colours is probably the explanation of that somewhat puzzling phenomenon, the success of the three-colour process before the use of plates really sensitive to red light.

It was shown by Dr. S. E. Sheppard and the author (*Phot. Journ.*, March, 1906) that more than half the record through many red filters upon the plates then in use was made by waves of less length than 6000 A.U. But pure reds are so luminous, even near their absorption band, that they are capable of recording sufficiently by such rays alone.

It has often been suggested that the blue filter should transmit some of the extreme red. Many such filters are in existence, and I have even been told that the use of such filters represents a departure of sound practice from "theory." The cause of the existence of such filters is, undoubtedly, that it is difficult to make a bright blue filter in which the red is completely absorbed.

But as to the "sound practice" it must be explained that until pinacyanol came into use there were *no* plates which recorded the extreme red transmitted by these filters, and consequently it was simply of no importance.

Even a filter made of methyl-violet, and appearing quite purple by daylight and bright red by gaslight, gives *no* red record at all on a pinachrome plate, and on a *pinacyanol bathed* plate the effect of the spectrum of daylight is about nine times as great at the blue end as at the red.

If, however, a filter such as rhodamine, which transmits all the red and orange, be used with a Wratten Panchromatic plate, the effect will be that a scarlet colour will register in the blue-filter negative as well as in the red, and consequently will be represented by magenta printed alone. With such a filter bright yellow will record in all three negatives, and be left as white in the print.

I do not think, therefore, that the blue filter should record any red whatever.

It is of great importance in three-colour work that the three negatives should be of the same gradation as nearly as possible. Should this not be so, a scale of greys produced by the superposition of three printings will differ in colour at the two ends. Such a scale may, for instance, have the

lighter tones of a bluish tint, while the deep tones are brownish. In order that the three negatives should be identical in steepness of gradation, it is necessary that they should all three be made on exactly the same kind of plate. Plates vary very greatly in the rate at which they develop, this rate varying in two consecutive batches of plates made in the same way. Consequently, if the three negatives be made on three different kinds of plate, even if these be simply the same plate bathed in different dyes, the rates of development are unlikely to be the same, and the gradations will be different to some extent.

It was formerly desirable to use three kinds of plate sensitised for the special spectral regions transmitted by each filter. Thus, a fast plate could be used for the blue filter, the same plate bathed in Orthochrome T or Pinachrome for the green filter, and the same plate bathed in Pinacyanol for the red filter. This was desirable, because only in this way could the shortest possible exposure under each filter be obtained. With the introduction of satisfactory panchromatic plates sensitive to the whole spectrum, this reason has disappeared, and it is now certainly the best practice to use the same panchromatic plate for all three exposures. Such a panchromatic plate, however, necessitates the employment of filters which cut accurately at the required points. A red transmission band through the blue filter is of no importance if the plate employed be not sensitive to red, but if a panchromatic plate be used, the blue filter must rigidly cut out red light.

Mr. Chapman Jones and Sir William Abney have shown that light of various colours does not produce the same gradation upon photographic plates. Experiments by E. Stenger show that the same statement is to a less extent true of plates sensitised with the isocyanin dyes.

A large number of measurements of the Wratten Panchromatic plate, when exposed through the three filters used in tricolour photography, have been made, and they show that the variation in gradation between the three curves is inappreciable, being very much less than in erythrosin plates, or even plates sensitised with a single isocyanin. Consequently, it may be safely assumed that if the three negatives are made on the same plate or on three plates

from the same box, and are developed together, the gradation of the three negatives will be identical.

The real difficulty of the subtractive processes lies in the selection of the printing colours.

These printing colours, by whatever method they are to be applied, whether as stained gelatine, in the stripping film or other carbon processes, as dyes, in the pinatype process, or as printing inks, must be, as nearly as possible, complementary to the taking filters. The practical importance of the colours of inks used for tricolour printing has caused Messrs. Wratten & Wainwright, Ltd., to issue a little booklet dealing with the subject, and also an Ink Tester for examining the colours of commercial printing inks.

The blue stain or minus red must be a bright blue-green, and, while it should appear very dark when examined through the red filter, it is important that it should not appear too dark when viewed through the green filter. This colour is usually the worst, and, as it is the basis of the greens, it is also the most important. Probably the best single dye is Patent Blue V, though this transmits the extreme red, which is bad.

The minus green should be a magenta, well on the *blue* side of crimson ; this colour never transmits enough blue.

Rhodamine B is a fairly good dye, but Xylen Red B is much better.

The yellow is very satisfactory always. For staining gelatin reliefs, I have found Pinatype Yellow D very good.

The effect of incorrect printing colours has been discussed to some extent under filters, and for further particulars the above-mentioned booklet should be consulted.

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